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Surveys of Communist World Scientific and Technical Literature

SPACECRAFT UTILIZING THE LIFTING REENTRY TECHNIQUE

PART II

Section I - Comprehensive Report

Section II - Annotated Bibliography

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ABSTRACT

This report (comprehensive report with annotated bibliography) is based on Soviet-Satellite open sources published 1957-1964, although some earlier articles are included. It is the first in a series of reports reviewing theoretical studies in lifting reentry. Part I (Reentry and Recovery of Soviet Manned Space Vehicles) was published as ATD Report P-64-60 (29 October 1964) and dealt with descriptions of launchings, flights, and reentries of Vostok-type space vehicles. Part II comprises two sections: Section I--a comprehensive report, and Section II--an annotated bibliography. Although the two sections are bound in one volume, they are independently paginated and have separate tables of contents. Section I (62 pages) is a comprehensive review of sources on theoretical and experimental studies of problems in fields of space sciences, i.e., problems of lifting and ballistic hypervelocity flight, and atmospheric reentry techniques. There are four parts following the Introduction: Group A. High-speed aerodynamics and gas dynamics; Group B. High-speed aerothermodynamics; Group C. High-speed flight mechanics; Group D. Strength of flight-vehicle components (thin and sandwich plates and shells). A brief conclusion is given. In writing this report articles and monographs having a closer relation to the reentry problem and showing either an original approach to the problem or a new method applied to its solution were selected from the bibliography and used. Section II (304 pages) is an annotated bibliography containing 861 entries arranged by subject in a manner similar to Section I: Group A. Aeromechanics of high-speed flows (451 entries); Group B. Aerothermodynamics of high-speed flows (168 entries); Group C. Flight mechanics (53 entries); Group D. Strength of space vehicle components (175 entries); Group E. Miscellaneous (14 entries). Within each subject group, the entries are further arranged chronologically by year of publication and source. There are three appendices to Section II: Appendix A. List of Source Abbreviations, Appendix B. Glossary of Abbreviations, and Appendix C. Alphabetical Index of Authors and Associations.

ATD Report 66-34 1 April 1966

Surveys of Communist World Scientific and Technical Literature

SPACECRAFT UTILIZING THE LIFTING REENTRY TECHNIQUE

Part II. Review of Theoretical Studies in Lifting Reentry (Report no. 1 in this series)

Section I - Comprehensive Report

Section II - Annotated Bibliography

ATD Work Assignment No. 52

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FOREWORD

The present document is the first in a series of reports on atmospheric reentry. The report is based on Communist World open technical literature available at the Aerospace Technology Division in the Library of Congress, covering primarily the period from 1 January 1957 to 31 December 1964. Some earlier articles (the earliest of July 1942 to December 1956) have been included.

Part I: Reentry and Recovery of Soviet Manned Space Vehicles, published as ATD Report P-64-60 dated 29 October 1964, deals with descriptive aspects of reentry problems. It covers the period between 1959 and 1964 and is based mainly on general technical literature and articles in the daily press of Communist countries on the launching of Soviet space vehicles.

Part II: The present report (No. 1 in this series) comprises two sections. Section I is a comprehensive review of papers published in Communist World scientific sources on theoretical and experimental studies relating to the problems of lifting and ballistic hypervelocity flight, and atmospheric reentry techniques. The materials on which this review is based have been arranged according to their content, as shown in the Table of Contents of Section I. All the papers reviewed were selected from Section II, which is an annotated bibliography containing 861 entries. The arrangement of this bibliography is as follows: The entries are divided into groups according to a fairly detailed subject matter breakdown (see Table of Contents, Section II). Within each subject group, the entries are further arranged chronologically by year of publication and source.

Both sections of Part II, the comprehensive review and the annotated bibliography, are here bound in one volume, with a colored separator sheet between them. The two sections are independently paginated: Section I thus contains pages 1 - 62, and Section II pages 1 - 304. Appendices A, B, and C, located at the end of Section II, consist respectively of a List of Source Abbreviations, a Glossary of Abbreviations, and an Alphabetical Index of Authors and Associations.

This Report will be followed by Report No. 2 of Part II which will also include ballistic reentry and will have the same arrangement as Report No. 1. It will contain information published on the topic in the Communist World during 1965 and the first half of 1966. The entries in the annotated bibliography in Report No. 2 will be numbered, starting with No. 1001.

SPACECRAFT UTILIZING THE LIFTING REENTRY TECHNIQUE

PART II

Section I - Comprehensive Report

ATD Work Assignment No. 52
(Report no. 1 in this series)

SECTION I

COMPREHENSIVE REPORT

TABLE OF CONTENTS

INTRODUCTION

The fields of science pertinent to the technology of the lifting reentry can be divided into the following prinicpal groups:

A - High-speed aerodynamics and gas dynamics, including rarefied-gas flows and design of minimum-drag bodies;

B - High-speed aerothermodynamics, including kinetic heating, injection cooling, and ablation shielding;

C - High-speed flight mechanics, including orbital and reentry mechanics, flight dynamics, oscillatory motion of flight vehicles, and meteorite hazards;

D - Strength of space vehicles, i.e., dynamic and thermal stress analyses of their components, mainly thin (solid, and sandwich-type) plates and shells

A more detailed breakdown of these groups can be found in the table of contents of this comprehensive report.

The articles and monographs having a specially close relation to the problem of reentry and showing either an original approach to the problem, or a method of its solution have been selected from the annotated bibliography and used in writing this comprehensive report. Kinetic heating with subsequent radiation, dissociation, ionization, and recombination processes in the air flow, and ablation and sublimation of the vehicle material are widely discussed topics related to the elements of the reentry process.

When reviewing the Soviet-Bloc literature one gets an impression of even more thorough discussion of topics associated with protection against the kinetic heating — porous cooling, ablation shielding, and thermal insulation — than of the kinetic heating itself.

Considerable attention is also given to problems in high-speed flight mechanics (see group C in the table of contents). The open scientific and technical literature associated with lifting-reentry elements leaves one with the impression that the scientists and engineers of the Soviet Bloc are capable of developing methods which will result in advanced reentry techniques.

The term "flight vehicle" is used in its broadest sense and includes spacecraft (space vehicles) and aircraft. The term "aircraft" encompasses airplanes, rockets, etc.

Group A. HIGH-SPEED AERODYNAMICS AND GAS DYNAMICS

1. Lift and Pressure Distribution

The distribution of lift and pressure over bodies in high-speed gas flows are very important to an aircraft designer. Around 1955 there were two methods for determining the pressure distribution over bodies of revoluation: 1) a method of linearizing the equations of motion, and 2) a method of characteristics. At that time A. A. Dorodnitsyn proposed a new method [269], based on approximate integration of equations of axisymmetric flow characteristics, which is applicable for small and large Mach numbers. The pressure distribution over an axisymmetric arbitrarily shaped body and other parameters in a plane-parallel supersonic flow with a detached shock wave are discussed in detail by O. M. Belotserkovskiy [282], who presents a critical survey of previous studies and various approaches to this problem. A mixed turbulent flow of a compressible gas in the region between the shock wave and the surface of the body is analyzed as well as the boundary-layer characteristics in that region. A computation method (based on Dorodnitsyn's method of integral relations) of reducing the problem to a numerical solution of an approximating system of ordinary differential equations is introduced so that the final results can be obtained with a desired degree of accuracy by using electronic computers. The parameters of a flow with a detached shock wave at $M_\infty = 3.0$, 4.0, and 5.0 past a circular cylinder are computed, and the results are presented in tables and diagrams.

The pressure distribution above airfoils in supersonic and hypersonic airflows has been investigated by E. Carafoli [387]; he gives some practical considerations in deriving a solution for a large range of Mach numbers from $M = 1$ up to the Newtonian region ($M_\infty \to \infty$). Expressions for pressure coefficients in flow behind a shock wave and for the Prandtl-Meyer expansion are derived and used for determining the aerodynamic characteristics of an airfoil (e.g., lift, moment, wave-drag coefficients).

The lifting force in rarefied-gas flows at hypersonic speeds is discussed in [124], and it is shown that the lift of large bodies (wedge, cone, etc.) at hypersonic speeds and arbitrary Knudsen numbers can be negative at any angle of attack between 0 and 90°. It is proven that this statement is applicable to a hypersonic flow of a continuum past bodies when the pressure distribution over the body can be determined by the Newtonian flow theory.

The qualitative analysis of slip-flow effects (the order of values of velocity and temperature jumps at the walls of a body) in a slightly rarefied-gas flow is presented in [205]; the effects of interaction and slip on flow parameters (friction, pressure) in a flow past a thin wedge are discussed, and the applicability of the boundary-layer theory is considered. The effect of velocity and temperature jumps on the heat transfer between the body and the heated basic portion of the boundary layer (where the temperature is proportional to the squared Mach number at infinity) is examined. The atmospheric entry of a space vehicle is the final and most formidable problem for a spacecraft returning either from

travel in space or from orbiting. An attempt to determine the effect of thermal radiation on the entry parameters is made by applying the relationships which are used in determining the parameters of a gas heated by a shock wave in a hypersonic flow past a slender body.

The solution of the entry problem of a slender body moving at high hypersonic speeds into the dense layers of the terrestrial atmosphere is presented in [427]. It is shown that radiation greatly influences the temperature and density distribution in the flow, whereas the pressure and velocity are less affected; numerical results of a calculation of the radiation effect on the flow parameters are presented in tables and diagrams.

The hypersonic similitude of temperature profiles in bodies during atmospheric entry at high velocities is discussed in [585]. The similitude conditions are examined, and it is found that the temperature profiles on the greater part of the entry trajectory (so long as the velocity is tically constant) can be determined by only one parameter. The effects of radiatvve heat excnange (with Sun, Earth, etc) and aerodynamics heat flow are examined, and the similitude parameters of temperature profiles in the presence of mass ablation, taking into consideration physicochemical transformaitons in the body material, are determined and discussed.

2. Radiation, Dissociation, Ionization, and Recombination Processes in Gas Flows

With the increasing kinetic heating of a gas, the processes of radiation, dissociation of molecules, and ionization and recombination of atoms take place in it, which affect the gas-flow parameters in many ways. The hypersonic flow of a radiating gas behind a shock wave in the vicinity of the stagnation point of a blunt body is studied in [133] taking into consideration the absorption process; the effect of the radiation (most essential in this region because of high temperatures and low velocities) on the flow parameters is investigated. The dependence of the extent of the radiation influence on the absorption coefficient and the optical thickness of the shock layer, as well as on the geometric parameters of the body, results in the effect of radiation growing with increasing absorption coefficient and body dimensions, and diminishing with increasing optical thickness of the shock layer.

The study of the dissociation process behind a shock wave facilitates the analysis of transient processes in perfect gases. The nonequilibrium dissociation of a two-component gas mixture, consisting either of two diatomic or one diatomic and one monatomic gas is analyzed in [137], and the results of a numerical calculation of process parameters (temperature, density, width of the relaxation region) for an oxygen-argon mixture at $M_\infty = 10.2$, $p_\infty = 10$ mm Hg, and $T = 298°K$ are discussed and illustrated by diagrams. When air passes through a very strong shock wave, it acquires a plasma state, and the processes of atom ionization and recombination take place in it. An analysis of these processes is presented in [541]. Formulas are derived for the coefficients of ionization by electron impact in the hot air from all energy levels, and for the coefficients of recombination (in cases of recombination with emission of a quantum of radiation, and as result of a three-particle collision) by using the hydrogenic approximation. The application of these formulas to the ionization and recombination of complex atoms is discussed, and an expression for a correcting factor (for the ionziation coefficient) taking account of the multiplicity of the atom is given. The variation of the parameters of a gas passing through a strong shock wave and the equilibrium behavior of the gas behind the shock are discussed in [94], using the equations of state conservation and relaxation as the initial ones. From an approximate solution of these equations (assuming a constant heat capacity), the width of the nonequilibrium-dissociation region is determined, as well as variations of gas parameters (e.g., density, temperature), in the equilibrium state and during the relaxation process. The gas-dissociation processes in the boundary layer at hypersonic velocities with $M > 10$ have a noticeable effect on friction and heat exchange. Analytical expressions for the laws of friction and heat exchange in a turbulent boundary layer of a dissociated gas derived in [578] are based on the limit-law theory and, therefore, do not contain (at least for large Reynolds numbers) any empirical constants. The comparison of numerical data concerning a certain friction parameter computed by using the formulas derived with data obtained by W. Dorrance (ARS Journal, v. 31, no. 1, 1961) shows satisfactory agreement.

3. Boundary Layer

Considerable attention is paid by Communist-World scientists to the investigation of plane and three-dimensional boundary-layer problems. Knowledge of the boundary-layer structure and properties is very important because the transport phenomena between the fluid flow past a body and the body surface are confined to this thin layer of gas. The study of a compressible boundary layer (at large velocities) is of especially great importance because of a considerable temperature increase due to frictional heating. An analysis of the parameters of a two- and a three-dimensional, compressible, turbulent, boundary layers over an arbitrarily curved surface is presented in [155], on the assumption that there are neither longitudinal nor transverse pressure gradients. Simple formulas are given for calculating the heat exchange on the faces and the surface of pointed and blunted cones under a given angle of attack (with regard to the shock curvature), and on a cylindrical surface in a slip flow.

The hypersonic similitude is an important tool in studying the hypersonic-flow problems, and has been considered in Soviet technical scientific literature by G. G. Chernyy, V. V. Lunev, and others. The similarity of two hypersonic flows which differ in scale is established by the intensity of nondimensional parameters and functions characterizing the flows. These similitude conditions are investigated in [389] for hypersonic flows past plane and axisymmetrical slender blunted bodies having on their surfaces turbulent boundary layers with variable entropy along their outer boundary. This boundary layer is developed within an inviscid highly turbulent high-entropy layer formed in the gas which passed through a section of an oblique shock wave near the stagnation point; the high-entropy layer has a high temperature and low density, so that the pressure is assumed to be constant. Equations of momentum and energy of the turbulent boundary layer are used in integral form together with empirical formulas to derive expressions which describe the similitude conditions investigated. A hypersonic-similitude law based on these expressions is formulated which states that the hypersonic flows past slender blunt bodies with a turbulent boundary layer will be similar if certain of their (enumerated) flow parameters and functions are correspondingly identical. The application of these similitude conditions to flows past bodies whose form is described by a power function, and to a laminar boundary layer is discussed.

The effect of thermal radiation and absorption on the parameters of the boundary layer is investigated in [73] by using a general system of equations of gas dynamics, taking radiation into account, for a laminar boundary layer, on a plate, and the solution is obtained (assuming the viscosity law $\mu\rho$ = const where μ is the viscosity coefficient and ρ - the density) in the form of a series in terms of two nondimensional parameters determining the radiation effect on the boundary layer; expressions are derived for the radiation flux into the plate, the velocity profile, and the skin friction.

Simplifications in boundary-layer analysis in plane and axisymmetrical flows of a radiating gas over surfaces like a double-wedge airfoil or a flattened nose of a body of revolution are discussed in [239]. Conditions are established under which certain simplifying assumptions (such as neglect

of some radiant-energy flux components) can be used, greatly reducing calculation without sacrificing accuracy. The wall temperature is assumed to be equal to that of the gas at the stagnation point, as in case of sublimation.

An interaction between a viscous radiating gas flow and the surface of a body at very high hypersonic speeds is examined in [163]. Computation results for conditions behind the normal shock at certain atmospheric-entry speeds (up to 10—15 km/sec), altitudes (up to 70 km), and temperatures (up to 20,000°K) are shown graphically and compared with the phenomenon of a steady gas discharge under high pressure.

The determination of the drag-velocity relationship in a turbulent boundary layer on a plate in a gas flow is discussed by using the Kármán boundary-layer equation and assuming a constant friction stress over the layer [364]; it is shown that the Kármán theory on the drag of a plate in an incompressible fluid can be easily generalized to gas flows with large Mach numbers. The results of the analysis are illustrated in diagrams by curves showing the dependence of a nondimensional friction coefficient on the Mach number values up to $M_\infty = 10$.

The flow of a compressible fluid in a steady turbulent boundary layer is examined in [437]; the velocity profile in the layer is determined, and the relationship between the friction stress on the wall and the thickness of the boundary layer is established for a thermally noninsulated wing and an axisymmetrical body.

The same problem in the case of accelerated or retarded motion, when an unsteady turbulent boundary layer is formed, is discussed in [323]; the variation in the location of the separation point is analyzed, and the effect of drag is evaluated. The boundary-layer parameters in sections close to the stagnation point are of special importance, particularly when the gas reacts chemically with the material of the body.

The equations of a laminar boundary layer at the stagnation point of a blunt body are used in calculating the parameters of a multicomponent boundary layer in the presence of chemical reactions on the body surface [152]. The burning of a body consisting of many elements (various carbon, oxygen, and hydrogen compounds) in a high-temperature air stream is analyzed, and the rate of burning and the surface temperature are determined. The burning of a graphite body is discussed briefly.

The problem of cooling the surface of a porous body by injecting a chemically active or inert fluid through its walls is often discussed in Soviet literature, in connection with the effects of gas injection on such physical properties as the heat exchange and skin friction in the mixture on the plate surface.

The laminar boundary layer characteristics on a porous plate in a gas flow with a fluid injected into the layer in the presence of chemical reactions are analyzed in [158]. The effect of chemical reactions on the heat and mass exchange is investigated, and the dependence of friction stresses, and thermal and diffusion fluxes at the wall on a nondimensional

fluid-injection parameter and the Mach number of the flow are established. The approximation and generalization of results obtained is used in deriving the engineering formulas which can be used in determining the necessary amount of coolant for porous cooling at a given surface temperature, the rates of burning, and the sublimation of the body material.

A laminar boundary layer on an axisymmetrical, blunt body moving at a high supersonic speed is examined in a steady flow at the stagnation point where the pressure and temperature conditions provide for phase change or evaporation [141]. The high temperature in the boundary layer allows the presence of chemical reactions. A numerical sample analysis is made for an oxygen flow past a graphite body with equilibrium chemical reactions in the boundary layer.

A steady flow of a binary gas mixture in a laminar boundary layer on a surface which causes a weak transverse mass flow (e.g., a porous or evaporating surface) is studied [130]; the physical properties of perfect-component gases are different, and their specific heats are independent of temperature. A general case is treated when the free-stream velocity and surface temperature are time-dependent, and the law of dependence of transfer coefficients on temperature is arbitrary. The equations of a two-component boundary layer are transformed into a system of three second-order nonlinear differential equations of the same form, which are reduced to a system of three linear differential equations. For integration of these equations, a certain method of linearization, called "the method of straight lines" is used. As an example the boundary-layer and gas-injection parameters in a gas flowing past a porous plate are discussed, and results of a numerical evaluation of a uniform injection of hydrogen into a boundary layer of air are presented in diagrams.

Suction of the boundary layer can be used to increase the flying range of winged aircraft. The optimum bleed on a porous plate in an incompressible gas flow over a plate is discussed in [204]. The optimum bleed means such a distribution of the normal velocity component on the plate surface such that the local Reynolds number in every boundary-layer cross section is equal to its lower critical value; a porous plate is one on whose surface the normal-velocity component is distinct from zero. Coefficients of laminar friction and the local and total amount of gas bleed are determined for the optimum-bleed conditions.

A laminar boundary layer consisting of two separate phases - liquid and gas - is analyzed in [191]. The liquid phase is formed on the surface of a body in a stream of gas by surface melting or by injecting a liquid through its pores. The densities of both the liquid and the gas are constant, and their physical properties are independent of temperature. Partial differential equations with boundary conditions for the flow of each phase and on their interface are given as well as their solutions. The interrelations of variations in the flow velocity, the rate of liquid-phase forming, and body-surface conditions are discussed. The second approximations in solving the problem of a laminar boundary layer on a plate under various conditions (e.g., constant Prandtl number and parameter $K = \rho\mu$ where ρ - is density, μ - viscosity conditions) with equilibrium dissociation taken into account

are derived in [89] for a thermally insulated plate and for a plate with a prescribed surface temperature. A numerical analysis of the boundary layer on such a plate for $M_\infty = 10$, 20, and 30 is presented, illustrated by diagrams showing the dependence of layer parameters (layer thickness heat content, velocity variation) on M. The error induced by assuming that K = const is pointed out.

4. Shock Waves

The study of shock-wave phenomena and relationships, and irreversible changes in gas and flow parameters in passing through a shock wave, e.g., decreases in velocity associated with increases in pressure, density, temperature, entropy, etc., are of vital importance in the kinetic heating, stagnation-point flow, and boundary-layer parameters.

A longitudinal, supersonic, gas flow past a body of revolution or a symmetrical airfoil with a forward detached shock wave of large curvature has been discussed in [250], and the effects of viscosity and heat conductivity of the gas (usually neglected in flows with shock waves of a smaller curvature) on the parameters of the flow behind the shock wave (flows have large velocity and pressure gradients in this case) are investigated. The continuity, impulse, and energy equations are used to describe the relationships between characteristics on both sides of the shock wave. The formulas of the temperature and pressure ratios ahead of and behind the shock wave are given, and the change of these parameters in the case of a perfect gas and their dependence on the Reynolds number are pointed out.

The dependence of the curvature of a shock wave on the curvature of the outer surface of an annular body of revolution in a supersonic gas flow is mathematically analyzed in [268]. A flow is considered when there is no bow shock wave in front of the whole body, and an oblique shock surface is attached to the leading edge of the body. The author comes to the conclusion that the law of dependence of the curvature of a shock wave on the sum of curvatures of the body and of the streamline in a conical flow is analogous to the law of dependence of the shock-wave curvature on the curvature of an airfoil in a plane-parallel flow.

The effect of the transverse curvature of a convex (cylinder) or concave (channel) surface on the turbulent-layer parameters in a high-speed flow in the presence of heat exchange is investigated in [200] for various Reynolds and Mach numbers and various values of certain temperature parameters, assuming that the molecular and turbulent Prandtl numbers are distinct from unity, the viscosity and heat-conductivity coefficients are independent of pressure (but dependent on temperature), and c_p is constant (c_p - is the heat capacity under constant pressure). Equations of an averaged steady gas motion in an axially symmetrical turbulent boundary layer without a longitudinal pressure gradient, and the equation of state are used in determining the temperature distribution, the velocity profile, and the drag law in the boundary layer. The results of computing the boundary-layer parameters and evaluating the surface-curvature effects for a cylinder (at $M = 0$ to 10, $Re = 10^4$ to ∞, and $T_w/T_r = 0.2$ to 1.0) and a channel ($M = 0$, 0.5, 1.0; $Re = 10$; and $T_w/T_\delta = 0.2$, 1.0, 2.0) are discussed and compared with experimental data in a number of diagrams. Here T_w is the wall surface temperature, and T_r and T_δ are the temperature of the outer boundary-layer surface for the cylinder and the channel, respectively.

The propagation of unsteady shock waves is investigated in [58] by an approximate method in which the equation of the state of the medium $p = p(V)$ (where p is the pressure and V, the volume) is replaced by a broken line $p = -A^2V + B$ (where A and B are constant along a segment); by

reducing the length of the straight segments, the desired accuracy in determining the wave parameters can be obtained. The propagation and reflection of a plane unsteady shock from a rigid wall is analyzed.

The propagation of an explosion shock wave is investigated in [78] by applying the method of integral relations to the total energy of the moving gas and using the piston-theory technique. An expression is derived from which the law of the shock-wave propagation and the pressure can be determined. The exactness of propagation-rate and pressure functions obtained is discussed for the piston expanding at a constant rate, and according to a power-law function; the case of a strong explosion is also analyzed. By using the law of plane sections (equivalence principle), the shape of the shock wave formed in a hypersonic flow past an airfoil or a body of revolution can be determined as well as the pressure distribution over the surfaces of these bodies, even in cases when their noses are slightly blunted.

The gas flows with plane, cylindrical, and spherical waves, induced by the propagation of a strong shock wave in a gas at rest, are studied in [119] by using the method of integral relations and the piston analogy in determining the gas parameters and motion. The application of some versions in using this method is discussed. In one version it is assumed that the pressure and velocity of all gas particles between the shock wave and the piston are identical, i.e., they depend only on time. The equations of conservation of mass, momentum, and energy are used as initial ones, and approximate results obtained show fair agreement with those of an exact solution. In another version, the self-similar solutions are applied by introducing in formulas for mass, momentum, and energy of the moving gas additional constraints which exist between these quantities in self-similar motions under like conditions. The procedure is outlined for determining the gas and shock-wave propagation parameters, which requires much computation. In a third version, the method of a "shock layer" is applied, in which the approximate distribution functions of velocity and pressure are used in the form of expansions in powers of a parameter characterizing the ratio of gas densities ahead of and behind the shock wave. An expression for determining the law of shock-wave propagation is derived. The problem of a detonation with the initial pressure taken into account, and of an unstable source of a gas flow in a compressible gas are discussed. The latter problem is encountered in studying the operation of shock tubes with a divergent nozzle.

Plane and axisymmetric gas flows with strong shock waves having a power-function shape are discussed in [82]. The high-entropy portion of the flow adjacent to the surface of the body carrying the shock is investigated, and it is shown that a correction in thickness of the high-entropy layer is necessary if exact solutions of unsteady self-similar gas motion are to be used in solving the corresponding high-entropy flow problems A method is presented for introducing such a correction, and for constructing the shape of the body for whcih the pressure distribution was determined by means of the small-disturbance theory.

A longitudinal supersonic gas flow past a slender pointed body of arbitrary cross section is investigated in [353], and the location and intensity of the front shock wave are determined by an asymptotic formula

based on methods previously developed by the author (PMM, v. 25, no. 3, 1961); it is assumed that the whole body is within the Mach cone constructed for the undisturbed flow and has its apex at the stagnation point of the body. It is discovered that the bow shock wave is a circular cone, close to the Mach cone, with the axis parallel to the flow direction.

The self-similar reflection of a plane shock wave is discussed and the relative position of the incident, reflected, and Mach waves investigated in [240]. The strength of a Mach wave at the wall is determined, and it is shown that a Mach wave cannot propagate either far ahead of or far behind the incident shock wave. The configuration of waves in the Mach reflection from a rigid wedge is analyzed. An expression for the reflection coefficient is derived, and the regular reflection is compared with the Mach reflection (in a triple point at a certain distance from the wall where the incident, reflected, and Mach waves intersect).

A simultaneous solution of systems of hydrodynamic equations (conservation of mass, momentum, and energy), and equations of state and relaxation is used in determining the distribution of vibrational energy of air molecules N_2 and O_2 behind a normal shock wave in the air [243], assuming that there is an equilibrium distribution of energy in translatory and vibratory degrees of freedom, and disregarding the dissociation, electron excitation, and ionization processes. In discussing the vibrational relaxation, the vibrational energy is related to a unit of mass (one mole). Results of computation for shock-wave velocities corresponding to M = 5, 9, and 20 are discussed and illustrated by diagrams.

A supersonic flow of a chemically reactive inviscid gas with rectilinear streamlines behind a plane-front oblique shock wave is discussed in [135]. A system of equations describing the flow, equations of kinetics with intital conditions, the equation of state, and relationships between density, velocity, and enthalpy of the gas mixture are used to derive expressions for the velocity and temperature variations in the flow direction behind the shock in terms of concentrations of the mixture components. The cases when the flow behind the shock wave is subsonic or supersonic are discussed, and the formulas obtained are applied to determining the parameters of shock waves in the air.

5. Minimum-Drag Bodies

The problem of determining the shape of annular bodies of revolution with minimum wave drag on the outer surface is solved in the framework of the linear theory in [267]. A simple explicit formula for a minimum-drag body is obtained under the assumption that the inner and outer flows past the body are independent of each other. It is shown that the drag does not vary substantially with the variation of geometric parameters of the body (in a reasonably practical range) if there are two unchanged initial cross sections (e.g., at the faces). Therefore, the derived drag formula can be accepted as a general law of drag. The drag coefficients of the rear part of a barrel-like body (tail part of a fuselage) are discussed, and numerical values calculated for M = 2.0 and 3.0 are shown in diagrams for bodies of various slenderness.

The problem of determining the shape of a minimum-wave-drag body of revolution is also given in [280] by using a variational approach. The solution of the variational minimum-drag problems is discussed in cases of a turbulent flow past a body of revolution with a given shock-wave shape, and past a plane body.

The problem of designing a generatrix for a body of revolution having minimum wave drag for the given velocity of the oncoming flow and coordinates of two points on the generatrix is presented in [339]. Cases when there is an attached oblique shock wave are discussed, using variational methods. The problem is a degenerate one and is solved by means of the calculus of variations for a particular given velocity of flow and geometric parameters. The computed drag coefficients for various coordinates of points on the generatrix and Mach numbers up to M = 5 are fiven in a table and are illustrated by diagrams.

The determination of the shape of an annular minimum-drag body in a axisymmetrical hypersonic gas flow is discussed in [340], under the condition that the pressure must be non-negative everywhere on the surface. The problem is discussed, using the calculus of variations, and expressions are derived for determining the drag coefficient, the coordinates of two points of the generatrix, and the optimum body contour. Results of numerical calculation of several optimum shapes are presented in a table and in diagrams.

An attempt to formulate and solve the problem of determining the optimal minimum-drag shape of a three-dimensional slender body in a hypersonic gas flow is presented in [218]. The initial expression for the drag coefficient is taken in such a form that the optimum shapes of the meridional section and of the cross section of the body can be determined separately. The first problem was determined long ago, so only the optimum cross-section shape is discussed. A variational problem is formulated, and expressions for determining the shape parameters and the drag coefficient C_x are derived. The optimum cross section determined is star-shaped, as shown in Fig. 1, and the variation of the drag-coefficient ratio C_x/C_x^o with the cross-section S/r^{o2} is plotted in a diagram (Fig. 2) (C_x^o is the drag coefficient determined for an equivalent Newtonian optimum shape of a body of

revolution and n is the number of chines.) The results obtained can be used in determining the minimum-drag shape of a body shown in Fig. 3.

Fig. 1.

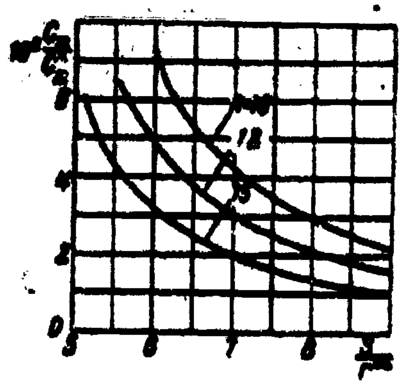

Fig. 2.

Fig. 3.

The wave drag of axially asymmetrical bodies in the form of a pyramid with a star-like cross section is discussed in [319]. The faces of the body have the shape of stream surfaces of flows behind the plane shock waves and their edges correspond to the lines of intersection of these shock waves. Formulas are presented for determining the geometric characteristics of these bodies, and the pressure and wave drag for given speeds (each Mach number is associated with a certain shape). In a diagram the pressure coefficients (wave drag) of pyramidal bodies and of equivalent circular cones are compared. The problem discussed in [319] is developed further in [110]. As exact solutions for the configuration of lift-producing bodies, the cutouts from stream surfaces of flows behind one attached plane shock wave, and behind two intersecting plane shock waves are used. Because the pressure on such surfaces is constant and equal to the pressure on a plate behind a plane shock wave, the problem of determining the pressure and lift on a plate in a hypersonic flow is discussed in the first part of the article. In the second part, the exact solutions are given for a V-shaped wing (Fig. 4) formed by two intersecting planes (in the case of one shock wave), and a pyramidal body (Fig. 5) with a V-shaped cross

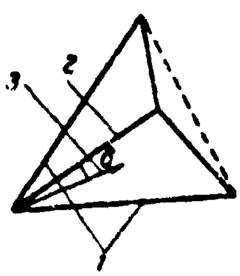

Fig. 4.

1 - Leading edge; 2 - intersection edge; 3 - undisturbed-flow velocity vector.

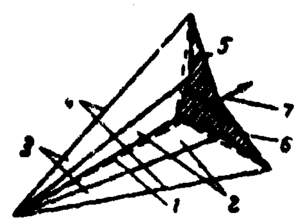

Fig. 5.

1 - Intersection edge of the body; 2 - body faces; 3 - wing faces; 4 - wing leading edges; 5 - wing trailing edges; 6 - base-parallel section; 7 - undisturbed flow velocity vector.

section (in the case of two shock waves). Both bodies have a delta shape with leading edges running along shock-wave boundaries. Formulas for the

lift and drag coefficients are derived and the interdependences between the geometry, lift and drag, and shock-wave parameters are discussed and illustrated with a number of diagrams. The wave drag (the surface pressure) of bodies with two plane shock waves can be infinitely reduced by a proper selection of their shape, thus making the whole drag significantly smaller than that of a wedge; the comparison of the drag of proposed shapes with that of a wedge at altitudes of 35, 45, and 55 and $M = 6$ is presented graphically and is discussed.

The problem of determining an optimum surface of a body in a gas flow which should either have minimum drag or maximum ability to dissipate the heat (i.e., the amount of heat transferred in a unit of time through the body surface must be a minimum) is considered in [211]. The gas motion satisfies the Navier-Stokes equations of continuity, energy, and state. The amount of heat absorbed by the body surface in a unit of time or the drag of the body is expressed in a general-form surface integral which contains heat-transfer functions depending on the shape of the body surface. Isoperimetric constraints (e.g., concerning the volume of the body, lift or moment of the wing) containing the same functions on the body surface are introduced, and a variational problem of finding the equation of the surface minimizing the surface integral is formulated and solved for both the heat-transfer and minimum-drag problems. A system of equations for determining the shape of a minimum-drag airfoil of a given cross-section area is derived, and its solution by successive approximations is indicated.

The total costs (of construction and operation) are generally used as the criterion of optimality of aircraft construction; the initial total weight can be sometimes taken as an optimality criterion because the changes in this weight are approximately proportional to the total costs. The latter concept of the optimality criterion is used in determining the optimum geometry of aircraft [395], under the assumption that its flight and tactical characteristics, and the useful load will not be affected by a change in the geometric parameters of some member; in other words, in case of such a change, the parameters of other members will be changed in such a way that these characteristics would be maintained; it is also assumed that the law of the aircraft motion with regard to the power consumption is known. Formulas are derived for determining the optimum value of optimized geometric parameters (dependent on or independent of each other), and also of other parameters to which the weight criterion can be applied. The optimum wing loading for a given flight velocity and altitude, and the optimum slenderness ratio of the nose of a fuselage (or of a fairing) are determined as illustrative examples.

6. Experimental Investigation and Equipment

Only a few articles on experimental aerodynamics are included in this report because the content of works in this field is clear from the annotated bibliography. A different approach to experimental investigation is used in [446] where the gas flow in electric-discharge devices is investigated, and formulas for its parameters and the range of application of the device are determined mathematically. The discharge device consists of a rectilinear closed channel of constant cross section filled with gas in which an electric discharge is produced at one end by electric energy continuously supplied; a column of heated gas is formed which expands and displaces the gas at rest. A moving plane shock wave is formed, followed by an impenetrable boundary (a piston) separating the column of heated gas from the disturbed gas which passed through the front of the shock wave. The process of displacing the gas at rest by the piston depends on the initial pressure and density in the channel, and the energy-supply pattern given by a power function of time. The gas which passes through the shock-wave front is assumed to be perfect, inviscid, and non-heat-conducting, and its motion is not accompanied by any physical or chemical changes. The disturbed-gas motion between the shock wave and the piston is regarded as self-similar. Expressions for velocity, density, and pressure in the disturbed region are derived, as well as the Mach number attainable (up to $M = 33$) and the duration of the process.

A complete description of the supersonic wind tunnel at the Traian Vuia Institute of Applied Mechanics is given with an accompanying diagram and photograph in [445]. The parameters of the flow (up to $M = 3.1$) are discussed, including the test results of a cone and a sphere at $M = 2.2$, and illustrated with photographs. The tests for determining the performance of the compressor station are discussed, and the cross-section area of the experimental zone of the tunnel is determined as a function of the Mach number. The arrangement of compressors for a larger supersonic wind tunnel is discussed, and accompanied by illustrative diagrams and tables.

The method of measuring the rate of shock-wave propagation in a shock tube constructed at the Institute of Applied Mechanics of the Academy of Sciences, Rumanian People's Republic, is presented in [180]. The time interval is measured for passage of the wave between two marks placed at a certain distance from each other. The instants of wave passage are registered by special low-inertia capacitance transducers. The time is measured by an electronic chronograph specially developed for this purpose.

Group B. HIGH-SPEED AEROTHERMODYNAMICS

The published material on the aerothermodynamic problems encountered in the study of high-speed gas flows involving thermal radiation, dissociation, ionization, recombination, thermal-boundary-layer and shock-wave formation are inseparably linked with high-speed aerodynamics and have been reported in sections 2, 3, and 4 of group A. This group (B) of published materials deals with aerodynamic heating of flight vehicles and with various means of protection against such heating.

1. Aerodynamic Heating

Aerodynamic heating is the main source of heat developed during entry of a flight vehicle from orbital or space flights into the atmosphere. The phenomenon of kinetic heating of vehicle structures is one of the most widely discussed topics in the Communist World scientific technical literature dealing with the thermal problems encountered in high-speed aircraft design. Gas flows past porous surfaces of plates and bodies with boundary-layer suction or injection of fluid into it, heat exchange between gas and body, heat transfer to aircraft structures, and determination of temperature fields in them — are the most thoroughly investigated problems; the more characteristic ones will be reported. The basic phenomenon which must be examined in discussing the kinetic-heating problem is the skin friction in gas flows. Some works concerning theoretical skin-friction analyses have also been mentioned in group A.

A formula in the form of a power function (obtained by interpolating experimental data) for calculating the surface friction in turbulent flows over a wide range of Reynolds and Mach numbers and temperature drops is given in [569]. A method was developed for direct measurement of local values of surface friction on a flat plate in a supersonic flow, and the measurements were carried out in the presence of intensive heat exchange between the flow and plate. The construction of a surface-friction pickup (for recording the static pressure) is described and possible methodological inaccuracies and errors in measuring are discussed. The range of applicability of relationships obtained, the influence of Reynolds and Mach numbers on the skin-friction coefficient, and comparisons with empirical values obtained by other authors are presented in diagrams.

The aerodynamic heating of a semi-infinite thin plate of finite thickness in a steady flow of a compressible gas with jump-wise increasing temperature is discussed in [556], assuming that the temperature of the plate is the same as that of the gas on the interface between the laminar boundary layer and the plate.

The dependence of the temperature of the leading edge of the plate on time, with consideration of heat flow through the edge, is investigated and exact solutions by means of the operational calculus are obtained for the following conditions of heat flow through the leading edge: 1) there is no heat flow, 2) the edge is artificially heated, and 3) the edge is artificially cooled.

The leading edge of a wing in hypersonic flow can be heated up to temperatures exceeding the melting point of refractory metals (even in cases of large sweepback angles), thus making cooling necessary. But, if the duration of such flights is short (for example, in quick entry and escape from dense layers of the atmosphere), a certain amount of damage to the surface can be tolerated. In this case, it is very important to know the rate of this thermal disintegration. In [660] such failure of the leading edge of a swept-back wing in a steady hypersonic gas flow, with evaporation of the material taken into account, is discussed. The solution of the problem is reduced to the simultaneous solution of a system of nonstationary (due to considering the advancing melting surface) equations of the boundary layer on the molten-material film; and of heat-conductivity equations of the solid remainder. Two cases are discussed in detail: 1) The material of the wing has a certain melting temperature and a number of transformation temperatures at which heat absorption takes place (metals and some ceramic materials disintegrate in this way); and 2) the material does not have a clearly marked melting temperature, the viscosity of the melt being a power function of the temperature (this is a disintegration pattern for various glasses). The behavior of both types of wing material is analyzed in respect to the formation of surfaces of evaporation, melting, and of transformations, and their propagation. Expressions are derived for the parameters of the ablation process and for the rate of disintegration.

The interaction (friction, heat transfer) between the gas flows and bodies on whose surface emission or absorption of a fluid takes place in a natural (for example, evaporation or condensation) or an artificial (suction or injection) way is often discussed in the Soviet technical literature. The effect of such artificial means on the heat and mass exchange in a turbulent boundary layer is analyzed in [562] where a fluid is injected into or a gas is sucked from the gas flow through the porous surface of a plate. A turbulent boundary layer is formed at the leading edge of the plate. An expression which connects the local skin friction coefficient with the suction or injection parameter is derived and its approximate solution is given. The results of a quantitive analysis conducted on the basis of the proposed theory are compared with experimental data obtained by other authors in diagrams which show fairly good agreement.

In many investigations of the effect of gas injection into gas flows past bodies, the variation of pressure in the direction of flow is not taken into account. Reference [225] gives the results of an experimental investigation of the influence of gas injection into a turbulent boundary layer through a porous plate on the dynamic characteristics of the turbulent boundary layer. The plate was placed in a hot-air flow with accelerating and adverse longitudinal pressure gradients. Gases of different molecular weight (air, carbon dioxide, and Freon-12) were injected. The following quantities were measured in the direction of flow (at Reynolds numbers from 10^5 to 5×10^5): dynamic and static pressures, temperatures of the injected gas, temperatures of the gas in the flow (450 to 550°K) and temperatures of the plate (375 to 420°K). The apparatus and the technique used are described. The effect of the physical properties and of the amounts of injected gases (at a certain pressure gradient) on the friction was established for various temperatures and

plotted in diagrams. The data obtained in processing the results were generalized and used in integrating the equation of motion. The procedure developed here for calculating the parameters of a boundary layer with a longitudinal pressure gradient is outlined point-by-point and is recommended for usage.

In previously mentioned works, the gases injected into the boundary layer were inert in respect to gases flowing past the porous surfaces. The case when the injected gas reacts chemically with the gas of the basic flow is of more practical interest. In reference [490], the friction and heat exchange in the turbulent boundary layer of a compressible gas flow are investigated when there are chemical reactions caused by injection of a chemically active fluid. It is assumed that the chemical reactions are instantaneous as compared with the rate of diffusion, which means that the temperature in the boundary layer is high and the thickness of the chemical-reaction layer is an infinitely thin surface as compared with the thickness of the boundary layer. The laminar and turbulent Prandtl and Lewis numbers are taken to be equal to unity. When calculating the characteristics of the boundary layer by the method used here, it is sufficient to know the distribution of concentrations, temperatures, and velocities only in the direction of flow. Expressions are derived for calculating the density distributioon, friction, the density of the gas mixture, and the heat flow into the plate.

A similar case of porous cooling, when one side of a porous plate is aerodynamically heated and its other side is exposed to a chemically active cooling fluid under pressure is discussed [560]. Cooling is achieved here by evaporation with chemical reactions, heating of the coolant in the pores, and heat transmission from the gas flow to the coolant. A method of filtration theory is applied in this investigation, assuming that the temperatures and pressures on both sides of the plate are constant and that no evaporation takes place inside the plate. Expressions are derived for the heat flow, diffusion flow, also for the coolant pressure required to maintain its flow through the plate, and the relationships between the criterional parameters of the gas in the flow, of the coolant, and the characteristics of the porous plate.

Approximate methods of determining the temperature distribution in flight-vehicle structures caused by aerodynamic heating have the advantage of simplicity in practical designing. The high surface temperatures and relatively low heat emission coefficient noted in flows at high altitudes and large Mach numbers make thermal radiation an important factor which can not be neglected. In [546], the nonsteady temperature fields in the vehicle structure are analyzed, with thermal radiation taken into account, and a convenient method for practical calculations is presented. The method consists in approximate solution of the heat conductivity equation with initial and boundary conditions by the method of finite differences. The flight is divided into time intervals $\Delta\tau$ and the structure into small finite parallelepipeds whose middle points are dealt with. The following assumptions are made: 1) the temperature gradient between points changes linearly with time; 2) the increase in the heat content of a "point" (parallelepiped) is proportional to its temperature increase; 3) the physical constants of the materials are independent of the temperature; and 4) the adiabatic temperature of the wall, the heat emission

coefficient, and the surface temperature are linear functions of time. A system of linear algebraic heat-balance equations for every "point" in the surface layer and inside the body is derived (the number of equations is equal to the number of "points") from which the variation with time of the heat emission coefficient, the temperature distribution over cross sections, and its variation with time on the surface can be calculated. The estimation of errors and their dependence on $\Delta\tau$ is discussed. The temperature distribution and variation in an aircraft during a 90-second accelerated flight from M = 2 to M = 10 at an altitude of 15,000 m are calculated, and the results are presented in diagrams.

2. Protection Against Aerodynamic Heating

The protection of flight vehicle structures, equipment, and crew against the consequences of aerodynamic heating by selection of proper insulating materials, arrangement of cooling, and use of ablation shielding seems to attract more attention from Soviet scientists working on aerothermodynamic problems than kinetic heating itself. The injection of liquid into the boundary layer (mentioned in the preceding subsection 1) can be used for cooling in cases of moderate kinetic heating. In cases of high velocity, as in atmospheric entry, ablation shielding, the most effective method of dissipating kinetic heat, is widely discussed in the Soviet literature concerned with the thermal protection of flight vehicles.

The basic conditions for any tipe of effective thermal protection are proper insulation of the vehicle skin and designing those shapes of vehicle which will ensure minimum heat transfer from the boundary layer into its structure.

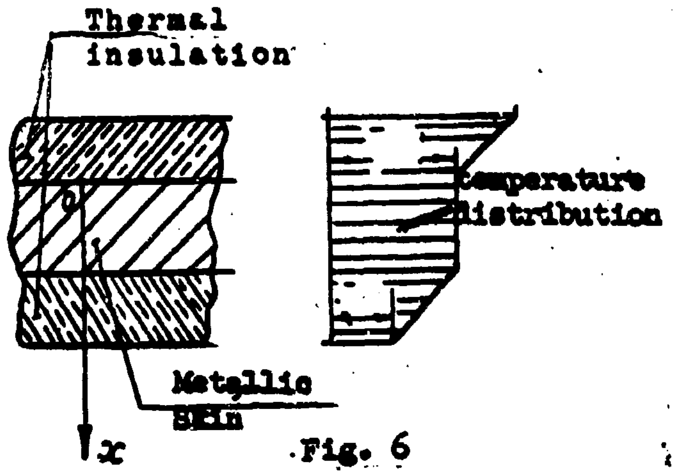

Fig. 6

One of the solutions of the skin-insulation problem is the three-layer skin construction. The outer surface of the metallic skin is usually covered by a heat resistant (for example, ceramic) layer and inner surface by a layer of fiberglass material. Heat transfer through such a plate, with a flow of hot gas on its outer surface, is discussed in [547], under the assumptions that the plate is infinite (the problem is one-dimensional) and the skin is thin (the temperature is constant along its thickness, Fig. 6), all heat from the boundary layer on the outer surface is used for heating the plate, the inner surface is heat-insulated, and the thermophysical characteristics of all materials are constant. An operational method (using the Laplace transform) is applied to determine the temperature distribution in insulating layers (linear in the outer layer and weakly nonlinear in the inner layer) for the given temperature of the gas in the flow.

The problem of thermal protection by designing that shape of a body in a hot gas flow which will ensure minimum heat transfer into the structure of the body is discussed [506], where that form of a thin airfoil is sought which will have a minimum mean heat transfer coefficient for a given lift, assuming that the upper and lower surfaces of the wing are thermally insulated and that the boundary layer is either laminar or turbulent, not mixed. The problem is reduced to solving the isoperimetric variational problem of determining that function describing the shape of the airfoil camber which will minimize the heat-transfer functional for a given value of the lift functional. The method of Lagrange multipliers is used in

solving the problem, and results of calculations in cases of a laminar and turbulent boundary layers are obtained which show the essential effect of the temperature on the heat-transfer coefficient and the weak effect of the temperature on the optimum shape of the airfoil.

Ablation shielding is the most effective means of protecting the crew and instruments against the heat developed during entry of space vehicles into the dense layers of the earth's atmosphere. Steady ablation is of special interest. Its fundamental problem — that of determining the constant rate of melting of a semi-infinite body heated by a constant heat flow on the boundary under arbitrary initial conditions is discussed in [615]. It is assumed that the molten materials are immediately removed, thus the thin molten film does not affect the melting process. The problem is solved by analyzing the flow of a high-temperature gas near the stagnation point of a blunt body having a melting temperature lower than the stagnation temperature. The equations of heat conductivity and of thermal equilibrium, with initial conditions are solved by the L. I. Rubinstein method (Akademiya nauk SSSR Doklady, v. 58, no. 2, 1947, and Izvestiya vysshikh uchebnykh zavedeniy. Matematika, no. 4, 1958), and a system of integral equations is obtained; from the asymptotic solution of this system, expressions are derived for determining the rate of melting and the process of heat transfer into the solid remainder of the body. The effect of a sudden change in the intensity of heat flow on the melting rate and heat transfer are analyzed, and the course of the melting process in the case when the heat flow varies arbitrarily with time is discussed.

When an axisymmetrical solid body begins to melt in a steady flow of a gas, then, under certain conditions (for example, when the heat-conductivity coefficient of the material of the body is high), a stationary process of ablation will take place and the melting front in the vicinity of the stagnation point advances at a constant rate.

The steady ablation process is discussed in [596] in a general form, and an exact simultaneous solution is obtained for the unsteady Navier-Stokes equations and the equations of the heat inflow (without dissipation) with proper boundary conditions. The steady regime of ablation at the stagnation point of a semi-infinite body in a plane and in axisymmetric flows of an incompressible fluid is discussed. The rotation of the solid about the flow axis is taken into account in the latter type of flow. Systems of nonlinear ordinary differential equations from which single-valued solutions can be obtained are derived in both cases. The possibility of extending these solutions to a compressible gas flow with variable coefficients of viscosity and thermal conductivity of the gas and of the liquid phase of the body material is mentioned.

Soviet authors devote considerable attention to the ablation of material from the surface of a body in radiating gas flow behind a shock wave. The solution of the thermal radiation problem for the boundary layer in the vicinity of the stagnation point of a blunt-nosed body is presented in [614]. The convective and radiative components of the heat flow are considered and the effects of their variation on the ablation rates, temperatures, and heat transfer to the body are examined; formulas for calculating these parameters are given.

The ablation process of a blunt body at the stagnation point (an axisymmetric problem) and along the stagnation line (a plane problem) in a dissociated air flow is investigated in [607], taking account of the evaporation of the molten-material film and the presence of an arbitrary number of endothermic "fronts," for example, sublimation, melting, etc., where absorption of heat can take place. Metals and some ceramic materials disintegrate in this way. Heat transfer in the solid phase, the rate of disintegration with an without evaporation are discussed, and the most typical cases of thermal failure, at low and at high stagnation temperatures, are analyzed in detail. At low temperatures, dissociation of the air is neglected and the boundary layer is treated as a binary mixture of the body-material vapor with air; at high stagnation temperatures, dissociation cannot be disregarded, and the boundary layer is handled as a three-component mixture of atoms of air molecules and particles of the body material. Expressions for determining the rate of ablation are derived in both cases. The solution obtained is generalized to the following cases: when there are heterogeneous chemical reactions between the dissociated air and evaporation products, and when boiling occurs in the melting zone with infinitely strong heat flows from the gas.

An exact solution of the problem of equilibrium and nonequilibrium sublimation of a blunt body at the stagnation point is presented in [610], assuming arbitrary dependence of the physical properties of the body material on time, and disregarding the effects of dissociation and thermal radiation in the gas flow. The variation of coefficients (of viscosity, heat conductivity, diffusion) in molecular transfer, and of criteria (the Prandtl, Lewis, and Schmidt numbers) under given conditions is discussed; the boundary problem is formulated, its numerical solution for the Prandtl number $Pr = 0.7$ and Schmidt number $Sc = 1.0$ is presented, and the results are given in tables; a solution of the problem is derived for arbitrary Prandtl and Schmidt numbers. A necessary and sufficient condition for boiling on the sublimation front is obtained, and expressions for the rate of sublimation are derived in closed form. The temperature profile in the solid is determined in quadratures. It is shown that the solution of any particular problem of sublimation can be reduced under these conditions to a solution of three equations to determine the concentration of gaseous products, the temperature of evaporation, and the rate of sublimation.

An approximate method of determining the law which governs the advance of the ablation front of centrally symmetric bodies in a variable heat flow is presented in [617]. A general qualitative result in the form of a differential equation is obtained first. Its solution is reduced to determining the ablation by only one criterion μ, not depending directly on the melting point. An approximate analytical solution for a plane wall and a constant heat flow is obtained from the basic "qualitative" equation which is reduced to a linear second-order equation that is solved, in turn, in terms of Bessel functions of an imaginary argument; the final solution is obtained in parametric form. The high degree of approximation of this solution is demonstrated in a graph where the curves obtained for various values of μ are compared with those plotted according to numerical calculation data of this particular case (of a plane wall in a constant heat flow) obtained by a method of finite differences.

A very important inverse problem of aerodynamic heating — that of determining in an analytical way the rate of advance of the melting front and the heat transfer into a body by using the data on the variation of the temperature with time at some point inside the body — is discussed in [613]. An approximate solution of this ablation problem is obtained for an infinite plate in a medium with a temperature higher than the melting point of the plate material, in the presence of physicochemical transformations on the surface of the heat exchange, assuming a uniform distribution of the initial temperature in the plate. The concept of the melting front is replaced by the concept of a surface at a certain temperature (of phase change or of disintegration) in the plate with coefficients of thermal conductivity and diffusivity changing in the same way as in the solid remainder of the body. Changes in the boundary conditions are divided into a number of time intervals such that the heat flow can be considered constant in each interval; the thermophysical characteristics are assumed to change step-wise when switching from one interval to another.

Formulas are derived for determining the rate of advance of the phase-change front from the data on the temperature variation in a cross section of the plate, and for determining then the temperature variation over the thickness of the plate from the rate of advance of the phase-change front and associated temperature of the phase-change. The effect of the step-wise treatment on the accuracy of the solution is analyzed in the case when the variation of boundary conditions is linear, and it is shown that the error in this case is directly proportional to the rate of variation in heat flow and to the thickness of the plate; it also depends on the length of the time intervals and on the plate material. Satisfactory agreement is found between the results of analytical calculations by this method and empirical data obtained from heat-exchange experiments involving the melting of a plate surface by electron-beam bombardment in an electric calorimeter with a known heat flow.

3. Experimental Studies

The experimental approach to the solution of ablation problems is very important because in some cases it yields the needed information more quickly and effectively than an analytical solution; very often the empirical results, formulas, and especially, the coefficients of the process are used in analytical investigations, to say nothing of the significance of the experimental verification of theoretical studies. Publication of some typical methods of experimental investigations is reported here.

The oxidation of metals and alloys in air flows at high velocities and temperatures with subsequent disintegration through corrosion, erosion, and burning of the material of the specimen is investigated experimentally in [618]. An installation consisting of a wind tunnel and a heating unit has been designed specially for this purpose (Fig. 7), and the technique of operation has been developed. The installation, specimens, and the methods of measuring and evaluating the disintegration and flow parameters are described in detail, and the dependence of the rate of disintegration on the flow velocity (up to $M = 3$), the angle of attack (up to 90°), the temperature (up to 1473°K), and the duration of exposure to the air flow (up to 2 minutes) is shown in diagrams for Armco iron and for iron-base and nickel-base alloys. The heat resistance of these materials, and the conditions under which they burn are discussed.

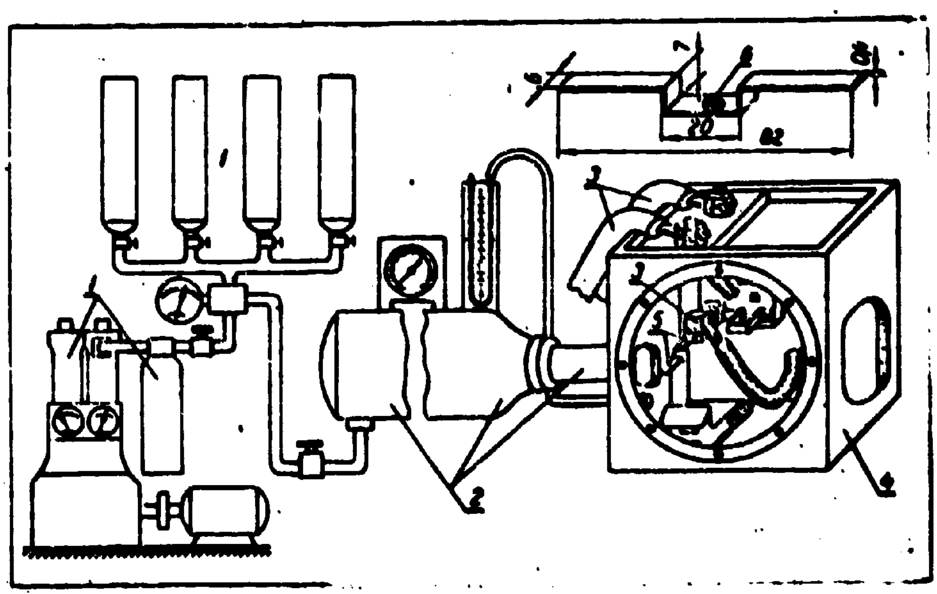

Fig. 7. Schematic diagram

1 - Compressor station; 2 - nozzle chamber; 3 - electric heating; 4 - wind-tunnel test chamber; 5 - specimen; 6 - area used for calculations.

When a thin film of molten metal moves on the surface of a body in a high-speed air flow, waves are formed on the film and this so-called "liquid roughness" increases the turbulence in the boundary layer, and thus, the heat exchange. An experimental study [612] was carried out in order to obtain a qualitative and quantitative evaluation of the effect of this film on heat transfer. A hollow glass-reinforced textolite cylinder 16 mm in diameter with a flat front face was placed in a supersonic flow. A film of molten tin on the surface of the front face of the cylinder was produced in two ways: by kinetic melting of a tin rod (4 or 8 mm in diameter) protruding 1 to 2 mm and axially movable through a central hole in the face, or by forcing molten tin through a porous chromium plug inserted in the same hole. The experiments were conducted at a stagnation temperature of 580°C and Mach numbers 1.8, 2.3, and 2.7. The two setups of the experiment, the equipment used, and the measurement technique applied are described. The rates at which the rod melted, the consumption of molten metal, the heat-transfer coefficient, and the temperatures are given in tables and diagrams for various parameter of the oncoming flow, and their interrelation is discussed.

Qualitative information on the melting behavior of bodies of certain shapes in supersonic flows can be obtained experimentally by using specimens made of fusible metals. Models made of Wood's alloy are used for this purpose [59]. The low melting point of Wood's alloy made it possible to carry out experiments in flows with relatively low stagnation temperatures (about 88 to 89°C); the flow velocity was M = 1.7. The test specimens were cones with bases 6 to 7 mm in diameter and apex angles measuring 10, 20, 30, and 50°. The melting process was observed and photographed by a IAB-451 apparatus. A device (kimograph) especially designed for the purpose was used for the time-related recording of the melting process. Two photographs of the disintegration of specimens are shown (Fig. 8 and Fig. 9).

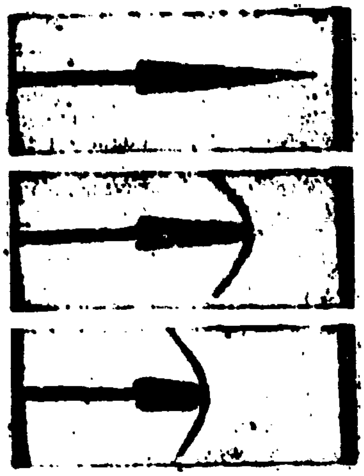

Fig. 8. Melting of a cone with a 10° apex angle at 88.8°C and M = 1.7.

The execution of experiments is described and the results obtained are discussed; the constant rate of melting (the decrease Δh of the cone length h with time) for various apex angles α is shown in a diagram (Fig. 10) as a function of time τ.

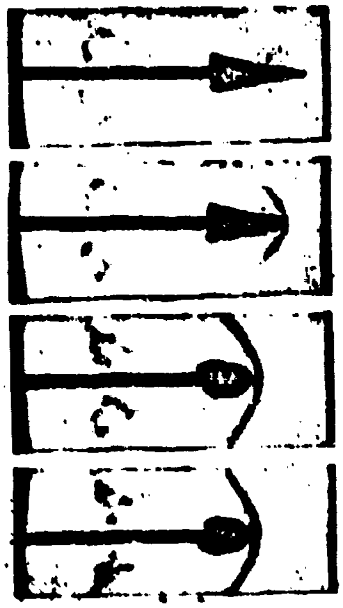

Fig. 9. Melting of a cone with a 20° apex angle at 88.8°C and M = 1.7.

An experimental investigation of the rate of melting of small cylinders and cones made of lead and of aluminum in a hot supersonic gas flow is described in [589]. The gas flow was obtained by means of a

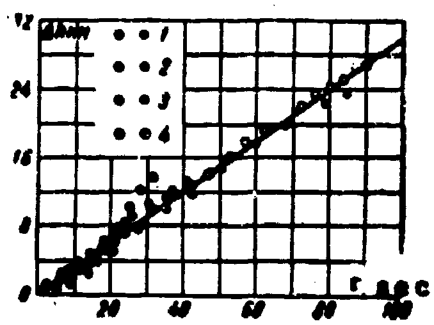

Fig. 10. Rate of cone melting

1 - Cone with α = 10°; 2 - α = 20°; 3 - α = 30°, 4 - α = 50°.

combustion chamber with a Laval nozzle; three types of specimens were used: 1) specimens for determining the rate of melting, the changes in their shape, and the supersonic flow patterns; they are solid lead and

aluminum cylinders and cones with 10, 20, and 30° apex angles; 2) lead specimens with protective noses made of materials that melt at high temperatures for testing the effect of the nose on the melting process; and 3) specimens with an axial channel through which cooled air is blown against the hot-gas flow so that a screen of cold air with a pressure higher than that behind the shock wave is formed around the specimen; the effectiveness of this method of protection against melting was investigated. The velocity range of the jet (30 mm in diameter) was M = 1.0 to 2.7, its temperature range — from 500 to 1000°C; the duration of operation was from 8 to 17 minutes, depending on the pressure and temperature in the combustion chamber. The arrangement of the unit and the specimens, the methods applied in measuring, recording, and evaluating the obtained experimental data are described and explained; the results of the investigation are discussed and compared in diagrams.

Group C. HIGH-SPEED FLIGHT MECHANICS

No publications directly concerning the mechanism of the atmospheric entry of flight vehicles could be found in Communist-World open scientific and technical literature. Only articles in periodicals on topics more or less associated with atmospheric-entry dynamics can indicate the state of research development in this field and show the means which are available for realization of new ideas. These topics concern the orbital and transfer motions of satellites, flights of winged aircraft at very high altitudes, gliding of lifting bodies from orbital and space flights, processes and phenomena associated with the entry into dense layers of the atmosphere (thermal radiation, dissociation of molecules, ionization and recombination of atoms), space vehicle control, and rocket dynamics, as well as articles concerning the effect of environmental conditions in space (e.g. gravitational fields, cosmic radiation, meteorite hazards).

1. Motion of a Variable-Mass Point

The most general problem of space-flight mechanics is the motion of a mass point in a gravitational field. The solution of nonlinear problems of motion is sometimes simplified by replacing the continuous changes in parameters (e.g. distance, velocity, density) by step-wise ones, by dividing the given range into sections in which the variable parameter under discussion can be regarded as a constant, or by confining the analysis to only one such step properly selected. An approximate solution of the problem of motion of a point of variable mass in a homogeneous central gravitational field given in [790] is based on an assumption that the motion takes place in a relatively narrow cylindrical (or spherical) layer of thickness Δr such that the value of the ratio $\Delta r/r_m$ (r_m - is the distance from the center of gravity to the middle surface of the layer) is so small that it can be neglected if compared with unity, in other words, that the magnitude of the acceleration of gravity in this layer is constant, though of variable direction. Such a field is called a homogeneous plane-parallel field. Differential equations approximately describing the motion of a variable-mass point with a restricted reactive thrust under these conditions are solved with the use of Pontryagin's maximum principle. The optimal programs for the control of thrust and its angle of inclination are obtained by maximizing the corresponding functional and by formulating and minimizing the Hamiltonian. The analysis of these programs leads to the establishing of five regimes for controlling the thrust under the condition that the switching function $\delta \neq 0$. When $\delta = 0$ and the velocity is constant, only a special-purpose control is possible.

The random thrust deviations caused by the errors associated with the realization of an established optimum-thrust program induce disturbances in the calculated trajectory of a body of variable mass. The effect of such variations in thrust on the motion of a variable-mass body in a constant-power flight in a gravitational field is analyzed in [837]. The optimal undisturbed motion of the body is discussed first. Then the errors caused by the thrust variations and by the inaccuracy in realization of initial conditions are examined as well as the induced declinations from the trajectory and the associated optimum corrections necessary to keep up the desirable program of the reactive thrust. A functional Φ concerning the acceleration due to the thrust in the case of motion with errors and corrections is formed; the minimum mathematical expectation of its increment ($\Phi - \Phi_{min}$) is determined for the optimum number of corrections and for their optimum distribution, and the effects of both on the motion parameters of the body are discussed. An approximate expression for the minimum total weight of the body (with the source of power and fuel supply) for the given value of Φ is also derived.

A similar problem of determining the optimum motion parameters of a body of variable mass in a gravitational field, taking into account the random processes of power decrease, is discussed in [641]. Assumptions are made that the source of power consists of a certain number of autonomous sections which are switched off when damaged, thus causing a step-wise reduction of the jet power, and that the weight of the source of power is constant. Two types of random-damage processes are considered: 1) processes stimulated by inhomogeneous external conditions (the probability of damage depends on the radius vector, i.e., is associated with the trajectory); and 2) internal processes and those stimulated by homogeneous external conditions (independent of the trajectory). The limit case when the source of power consists of a large number of sections is also discussed; the step-wise decrease of power in this case is approximately replaced by a continuous one. In all these cases the solution of the problem is reduced to finding the extremals of the acceleration functional Φ, which is properly transformed for the case in question (e.g. by introducing the acceleration of gravity). Examples of the motion analysis of a variable-mass body with the step-wise power decrease caused by random damage of type (1) and in case of a continuous power decrease are presented. An example of motion with the source of power switched off is also discussed under the assumption that in this case no damage to the source of power can take place.

2. Motion of an Artificial Satellite

It is very important to know the changes in the orbit of a satellite caused by decrease of atmospheric resistance with altitude and by changes in velocity. The problem of determining such deviations of a satellite from an ideal (undisturbed) elliptical orbit (calculated without regard to the braking effect of the atmosphere) with an eccentricity $\varepsilon \geqslant 0.01$ is solved in [621], considering only the atmospheric drag X as the disturbing force, and, assuming the effect of X to be small, thus applying the method of small disturbances.

The equation of the undisturbed motion of a satellite in vector form is used, and after certain transformations the equation of a slightly perturbed motion of the satellite is derived from which the expressions describing the changes in the altitude and in the duration of one revolution are obtained, so that from the known elements of an unperturbed elliptical orbit (focal distance ρ and ε), a satellite-construction parameter $\lambda = C_x \cdot S/2m$, and variation of density with altitude, these changes can be calculated. Here C_x is the drag coefficient, S is the cross-section area, and m is the mass of the satellite.

The change of the trajectory of a satellite is of great importance, e.g., in solving the rendezvous and docking problems. Therefore, the problem of changing the plane of a satellite orbit at velocities close to circular orbital ones with a minimum decrease of velocity as discussed in [652] is of interest. This maneuver of a spacecraft at small angles of inclination to the local horizon is treated by means of the calculus of variations as optimal with respect to the loss of velocity. It is shown that under these conditions, the optimum regime is that at a practically constant angle of banking γ and angle of attack α corresponding to the maximum of the hypersonic lift-to-drag ratio $L/D = k$. Finite expressions for the conventional dependence of aerodynamic characteristics on the angle of attack are obtained in a form suitable for optimal programming in a general case by using α and γ as independent variables. The optimum-regime parameters (γ, α, and k) in declination of the plane of an aircraft orbit by a given angle with a minimum deceleration is also discussed in a case when the altitudes at the beginning and at the end of the maneuver are prescribed.

The presence of an atmosphere around a planet is used to decelerate a space vehicle approaching the planet. The degenerate elliptical orbits (braking passes) after which the satellite either lands or is maneuvered into a circular orbit far beyond the "boundary" of the planetary atmosphere are of

a certain interest because there exists a possibility of realizing planetary entry by using a special landing device and leaving the basic vehicle in orbit. The transfer of a space vehicle, which enters the atmosphere at a velocity higher than that of escape, to a circular satellite orbit is discussed in [643]. The magnitude of the additional impulse necessary for transfer of the vehicle from a braking pass to a given circular orbit is investigated and it is shown that a minimum thrust impulse is needed at the instant when the circular orbit is tangent to the braking ellipse in its apastron. A simple formula is obtained for determining the optimum increase in transfer velocity which depends on the altitude of the prescribed circular orbit.

The investigation is based on the assumptions that the gravitational field is a central Newtonian one, the altitude of the circular orbit is much greater than the atmospheric "boundary," the motion of the vehicle takes place in the plane of the prescribed final orbit, and the "atmospheric" portion of the braking passes is so small in comparison to their length that their trajectories can be treated as ellipses.

The deceleration of an artificial satellite in a planetary atmosphere causes secular and short periodical changes in the form and dimensions of its orbit. No studies concerning the short periodical orbit perturbations caused by the resistance of the atmosphere, such as those presented in [624], are known. The general type of the first-order perturbations in elements of a satellite orbit induced only by atmospheric resistance is determined under the assumptions that the Earth's atmosphere has a strictly spherical distribution and its density is a decreasing function of altitude, and that the Earth's gravity can be replaced by that of a mass point in its centroid and having the same mass.

The functions on the right sides of the Lagrange equations describing the perturbations in the plane of an elliptic orbit are expanded in trigonometric series of functions with the average anomaly as the argument. A system of differential equations containing Fourier expansions in terms of M is obtained from which the secular and periodical perturbances can be determined, the latter being either odd or even functions of M (either equal to zero or reaching the extremal values in apogee and perigee respectively). A numerical example of computation is presented, and it shows that the periodical perturbances are small and can be disregarded in evaluation of visual and rough photographic observations.

The motion of an artificial satellite with consideration of the atmospheric resistance in a noncentral gravitational field is a very complicated problem, and its solution is

almost impossible without the use of a high-speed electronic computer. In [620] a method is presented for convenient computer calculation of the motion parameters of a satellite, with the resistance of the atmosphere (rotating together with the Earth) and the deviation of the gravitational field from the central one taken into account; the disturbing action of the Sun and Moon are neglected. A closed system of differential equations in terms of osculating elements supplemented by an equation giving the dependence of the true anomaly on time is used to derive a system of equations completely determining the motion of the satellite; the effect of the noncentrality of the gravitational field is accounted for by introducing the components of the disturbing acceleration induced by this deviation.

The results of a numerical calculation of the orbit parameters of a satellite in a 700-day motion are presented in a diagram and their variation is analyzed.

3. Flight-Vehicle Dynamics

The laws governing the motion of various flight vehicles (airplanes, guided missiles, ballistic rockets, rocket-powered vehicles) under various conditions of motion (steady, unsteady and quasi-steady motions) are discussed, and their paths of flight are analyzed in a monograph [642] under the following basic simplifying assumptions: 1) the medium in which the flight is performed is invariable with time; 2) the vehicle is a body of variable mass with a rigid skin; 3) transient processes inside the vehicle (e.g. motion of fuel in tanks) is neglected; and 4) only the terrestrial gravitational field is considered. In the first part of the book, the possible and optimal trajectories of flight vehicles are discussed only from the kinematic point of view (the laws of variation in velocity, altitude, et cetera, with time) without touching upon the control problems. The vehicle control and the analysis of the stability of its motion will be the content of a future, second part of this monograph.

The equations of motion of a flight vehicle are derived, and mathematical fundamentals and initial data for determining its trajectories are briefly discussed. The steady motion of vehicles, their transient motions in the vertical and horizontal planes, the three-dimensional maneuvers, the range, and the takeoff and landing characteristics are analyzed.

The methods of the calculus of variations are widely applied to finding the optimum regimes of aircraft control because they enable an analyst to select from an infinite variety of possible regimes of motion (usually described by nonlinear differential equations) the narrower classes of motion for which the nonlinear equations can be integrated in quadratures. The motion of an airplane equipped with a liquid-fuel reaction engine on a circular orbit about 60 to 120 km over the earth's surface at speeds on the order of $M > 10$ is analyzed in [651], the aerodynamic forces calculated by Newtonian theory. The optimum angle of attack corresponding to the maximum lift-to-drag ratio is determined by optimizing the function which expresses the L/D ratio analytically. From the equations of motion of the airplane centroid (treated as a variable-mass point) in terms of projections of forces on the tangent and on the normal to the trajectory, expressions for the functionals T and L are derived which determine the duration of the flight and the corresponding distance respectively. By using T and L the solutions of the following variational problems of flight dynamics are given: 1) to determine a law of the mass variation of an orbital airplane during the flight such that a) the power-flight section of the trajectory will be a maximum; b) the power-flight duration will be a maximum for the

given amount of fuel; and c) the power-flight section will be a maximum for a given time of flight. 2) To determine the extremal power-flight times for a given range and for a given amount of fuel.

In problems of determining the optimum regimes of flight under given conditions, the feasibility of controls (their characteristics) must be considered; otherwise, the solutions could not be realized in some cases. The problem boils down to the selection of an optimum control system for an aircraft, which is discussed in [650]. An attempt is made to obtain a more general solution of the problem by supplementing the equations of motion of the aircraft centroid by equations of its motion about the centroid and by utilization of the Pontryagin maximum principle in formulating the optimization criteria. The motion of an aircraft in the vertical plane is analyzed for the case of a power flight in a homogeneous gravitational field assuming that the drag variation and the regime of engine operation are given functions of time. A system of differential equations of motion and kinematic relationships is written whose solution depends on the selection of the time function $\delta(t)$, where δ is the rudder angle, and on the initial values of the velocity components, centroid coordinates, and thrust angle Ψ. The conditions of the optimality of the control system (the values of δ and Ψ) are determined, and it is shown that optimum control can be realized either as a step-wise control (by alternation of δ_{max} and δ_{min}) or as a special-purpose control (Ψ = const., $\delta = 0$). A system of necessary and sufficient conditions (initial, final, and for switching) for the realization of both types of control is given in a table and discussed at length.

At flight speeds close to orbital, a winged space vehicle or a lifting body has a large reserve of kinetic energy which can be used in gliding flight. It is impossible to obtain a closed general solution of the variational problem of determining the optimum trajectory in this case. Therefore, the problem is solved in [635] by an approximate method, where the gliding process is treated as a uniform quasi-steady immersion of the vehicle in the atmosphere at an altitude of 70 to 75 km with overloads not exceeding 4 to 5 G's. It is assumed that terrestrial gravitation does not change with the altitude, that the atmosphere is isothermic, and that the flight is nonpowered. Using the equations of motion in terms of the the projections of forces on the normal and tangent to the path of gliding, the kinematic relationships, and the equation of the L/D-curve, a system of three equations describing the trajectory of gliding is obtained. These equations contain four unknown functions (density ρ, glide angle θ, and lift coefficient C_y), so that a constraint must be imposed

on one of them. Solutions are given for the following cases: 1) gliding range for ρ = const.; 2) gliding with C_y = const.; and 3) gliding with a constant glide angle relative to the local horizon. Results of a calculation for an initial speed of 6 km/sec, initial density of 8.34×10^{-5} kg/sec^2/m^4 (at an altitude of 49 km), $C_y = 0.141$, wing loading of 500 kg/m^2, and drag coefficient at zero angle of attack $C_{xo} = 0.02$ are presented in diagrams for lift-to-drag ratio values K = 3.5 to 0, and comparison with the data of an exact numerical solution shows that the results are almost identical. This article and the following ones in this group are the few publications closely associated with the lifting reentry problem, particularly its final stage—maneuvering in the earth's atmosphere and landing. Its content can be applied either to gliding of a winged reentry vehicle or a lifting body.

The maneuvers of a space vehicle in a gravitational field can be executed by applying the thrust either in the direction perpendicular to the radius vector of the vehicle (transverse thrust) or in the direction parallel to its velocity vector (tangential thrust). The motion of a spacecraft with a small transverse thrust in a central gravitational field is discussed in [647], treating the vehicle as a mass point. As initial equations, the equations of motion are used in polar coordinates (r, φ) in terms of nondimensional parameters $\rho = r_0/r$, $z = r_0\mu/\beta^2$, and $r_0{}^2 f/\mu = \varepsilon$, where r_0 is the radius of the initial circular orbit, μ is the gravity, β is the double areal velocity, and f is the acceleration of the transverse thrust. The quantity ε—the thrust-to-gravity ratio on the orbit—is considered as constant and small. The equality

$$\rho = z(1 + 2\varepsilon \sin\varphi + \varepsilon^2 R)$$

containing a new unknown function R is substituted for ρ in the initial equations of motion. The introduction of a "correcting term" $\varepsilon^2 R$ is a significant peculiarity of the solution, and contributes to its accuracy. In solving this modified system of initial equations, an expression for R is derived in terms of the functions of the argument $x = 4\varepsilon\varphi$. A comparison of the trajectory parameters calculated for various values of x, both with the "correcting term" taken into account and without it, is presented in tabular form, and it shows that the results obtained with the consideration of this term are more accurate.

The maneuvering of a space vehicle into a prescribed circular orbit around the Earth from some point in space at an arbitrary value of its velocity vector is a problem encountered in the return of a vehicle from a space flight. This problem is discussed as a particular case in solving the

variational problem of a transfer between two points in a central gravitational field discussed in [648] as a plane problem of transfer in a minimum time, under the assumption that a constant acceleration is imparted to the vehicle by its engine. The distance between the points is given by their radius vectors. In solving the system of differential equations of motion, a time functional is obtained whose minimization gives the solution sought. The Lagrange method is used, and the final equations obtained are solved by numerical integration on the BESM-2 computer, considering two problems: transfer between two circular orbits and placing a vehicle into a circular orbit from a point in space. In the latter case it is shown that the time required for transfer by means of thrust tangential to the trajectory and the time for transfer by thrust parallel to the velocity vector are practically the same.

The control of the rotary motion of a body in a space flight by means of a system of reactive torque-producing nozzles is usually reduced to the selection of their thrust-regime programming in accordance with the conditions of the given particular problem. The determination of the optimum law of operating the reaction-nozzle engines in decelerating the angular velocity of a rotating symmetrical body which performs a free motion in space around its center of inertia is discussed in [654]. Two basic regimes of retarding the rotation are discussed: 1) in the shortest time (unlimited fuel consumption), and 2) with the minimum fuel consumption (unlimited time). In certain particular cases, they can coincide. This search for a time-optimum regime is based on the assumptions that the nozzle engines produce control moments of limited magnitude around the principal axes of inertia of the body and that the inertia moments of the body and the directions of its principal axes are invariable. The solutions obtained in cases (1) and (2) are analyzed, and it is found that in case (1) all three engines retroact simultaneously up to the complete cessation of rotation, and in case (2) the transverse torques act in turn and the longitudial torque (along the axis of symmetry) acts continuously up to elimination of the longitudinal component of the angular velocity. As a particular case of braking the transverse rotation — the stopping of the precession, i.e., elimination of transverse angular-velocity components — is discussed as well as the construction of phase trajectories, i.e., the order in switching the nozzle engines on and off.

An original discussion of the interesting and important problem of the free-fall of a mass point in the cabin of a satellite during a free flight and a flight in the Earth's atmosphere is presented in [836]. From the equations (in vector form) of motion of the mass center C of the satellite (in coordinates with the origin in the Earth's center) and of

the falling mass point M (coordinate center in C) in a free flight when only gravity forces are acting, a second-order differential equation for the free fall is obtained whose general solution contains six constants for which the parameters of the elliptical orbit are taken. The derivatives of the radius vector with respect to these parameters represent the particular solutions of this differential equation. By means of these solutions, six radius-vector functions q and their time derivatives $\dot{q}$ are written. The vectors ρ and $\dot{\rho}$ which determine the position of M in the cabin and its velocity, in a coordinate system with the origin at C, are determined in the form

$$\rho = \sum_{s=1}^{6} C_s q_s, \qquad \dot{\rho} = \sum_{s=1}^{6} C_s \dot{q}_s,$$

where C_s are constants determined later from the conditions of an impactless separation of M from the cabin. The separation processes of M at the instant when the satellite passes its perigee and when it is in a circular orbit are discussed. The problem of determining the path and velocity of a mass point falling in the cabin of a satellite is also examined in the presence of nongravitational forces which perturb its Keplerian motion. The effect of the atmospheric drag, as such a perturbing force, on the motion of M is analyzed in the case of a circular orbit.

4. Spaceship Oscillation

The oscillatory processes in the motion of flight vehicles are of great importance for their design and operation. This importance increases with growing flight parameters (e.g., speed, pressure, temperature). In this section, only publications are reported which concern the oscillation of a rigid vehicle as a whole, either about its center of mass or relative to its trajectory, disregarding its deformations. Publications on the vibration of aircraft considering the associated stresses and strains are reported in group D, section 2.

The oscillation of an artificial satellite around its center of mass under the action of gravitational moments during its motion in an elliptic orbit is discussed in detail in [645a], with special attention being paid to the effects of resonance. An investigation of the conditions for the existence and stability of the state of relative equilibrium of a satellite (i.e., equilibrium in an orthogonal coordinate system with its origin in the satellite centroid) and a librational motion around this state was carried out by the author in ISZ, no. 3, 1959, 13-31. In the present article, the small forced plane oscillations of the satellite (induced by the ellipticity of the orbit and described by an equation of the pitch-angle variation) in the plane of its orbit are discussed, and a formula describing the associated forced oscillations of the eccentricity of the orbit is derived. The steady-state oscillations in the case of a parametric resonance are analyzed, and the region and magnitude of resonance values of the natural frequency are determined. A criterional inequality is derived which shows the domain of nonsteady oscillations. The resonance values of oscillation parameters in the case of three-dimensional oscillations are determined by supplementing the equation of the pitch-angle variation with those of the roll and yaw angles.

Solutions are obtained which describe the transverse oscillations of a satellite in an elliptic orbit and in a circular one (by putting the eccentricity of the elliptic orbit equal to zero). The only value of the frequency parameter at which the parametric resonance in transverse oscillation can take place is determined.

The problem of controlling the self-induced plane oscillations of a spaceship relative to its trajectory by an impulse-type automatic control system is discussed in [646] under the assumptions: 1) that the sensors of control system which record the angle of deviation of the vehicle from the prescribed direction have certain dead zones on whose boundaries discrete control impulses of a constant magnitude are produced by the servos; 2) the sensors and servos are of arbitrary nature; 3) the duration of a control impulse is

short, so that during that time the angle of deviation does not change, and thus the angular velocity changes step-wise; and 4) the perturbing moments acting upon the vehicle are constant in magnitude and direction. Assumption (2) permits omitting consideration of the fuel consumption and discussing instead the consumption of energy, which is given for a certain time t by a formula $G = ngt/T$, where n is the number of impulses in one cycle, g is the known energy consumption in one impulse, and T is the duration of a cycle. The formula shows that for finding the energy consumption the values of T and n must be determined.

The self-induced oscillations in unperturbed motion (i.e., the absence of perturbing moments) and under constant perturbing moments are discussed, and the energy consumption and duration of a cycle are determined in terms of nondimensional parameters of perturbing and controlling moments. The relationship between energy-consumption and disturbance parameters is established and illustrated by diagrams.

The oscillatory motion in the vertical plane of a winged solid-propellant rocket in powered and non-powered flights is studied in [633]. An analytical solution in the form of finite formulas and tabulated functions is obtained for determining the parameters of this oscillatory motion occurring when the steady motion of the rocket is perturbed, e.g., by deflection of elevators, cut-in and cut-off of the engine, or when the thrust becomes eccentric. The following principal assumptions and constraints are used: The incidence angles of wings and control surfaces are fixed, and the eccentricity of thrust is constant; the angles of attack α and of inclination of the vector velocity are small; the drag coefficient is constant and the derivatives of the coefficients of aerodynamic forces and moments with respect to α and to angular velocity are independent of the flight velocity; the mass and centroid of the rocket and the thrust are constant during the burning of the propellant. Linear equations describing the dependence of the lift and of the pitching moment on the angle of attack and angular velocity are used as initial ones, and a second-order linear inhomogeneous differential equation with constant coefficients which describes the motion of the rocket is obtained. In this equation the distance along the trajectory is taken as the argument. The solution of this equation is given, the oscillatory behavior of statically stable and unstable rockets in flights with the engine switched in and shut down is analyzed, and the coordinates of motion of the centroid are determined. The term "statically stable" ("unstable") is applied to a rocket whose $m_z^\alpha < 0$ ($m_z^\alpha > 0$), where m_z^α is the derivative of the pitching-moment coefficient with respect to α.

5. Meteorite Hazard

The encounter of a space vehicle in flight with meteors and meteoric particles (micrometeorites) is very probable, and measures for protecting the vehicles against punctures are developed in two ways: theoretical and experimental investigations of the nature and mechanism of the puncture process at velocities on the order of 10 km/sec or more, and the design and construction of protective means (e.g., increase of the wall thickness, special shielding) to prevent punctures. Results of an experimental observation of the mechanism of impact of two bodies—one of a small mass, the other of a large mass—at velocities of 3 to 7 km/sec, and X-ray photographs of the process of interaction between them at velocities up to 2 km/sec have been used in [672a] for a first-step solution of the impact problem at very high velocities by constructing an impact model which retains the basic features of the phenomenon and permits determining the fundamental parameters of the impact process. The mechanism of impact of a cylinder on a semifinite wall is shown in Fig. 11.

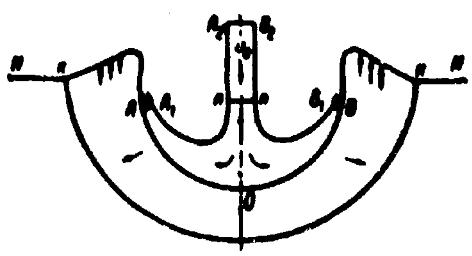

Fig. 11

The cylinder is partly melted in the impact and takes on a mushroom shape $OAA_1A_2B_2B_1B$; KK and nn are are shock waves in the wall and cylinder respectively; the metal between KK and nn is in a liquid phase and is about to be ejected. The impact problem is reduced to the investigation of the motion of this liquid, assumed to be incompressible, and is solved by means of classical methods of hydrodynamics for cases of potential and vortex motions. Formulas for the geometric parameters of a crater in the solid related to the length and diameter of the impacting cylinder and density parameters of the cylinder and wall materials are given. Results of calculations for impact velocities from 11 to 88 km/sec for various geometric and density parameters are given in a table. If less than the whole liquid phase is ejected from the crater during impact, an "inertial" increase of the crater takes place, i.e., the remaining liquid produces a certain additional deepening.

The first logical and simple measure to protect a space vehicle during its flight beyond the Earth's atmosphere against puncture by meteorites is to increase the wall thickness. But, a considerable increase in the weight of the vehicle in this case makes it necessary to search for other means of protection. A protective method proposed by F. Wipple (Astronomical Journal, v. 52, 1947, p. 131) is based on the assumption that in the impact an explosion occurs, and the meteorite and a certain amount of the wall material evaporate; thus the vehicle should be enveloped in a mantle (with a gap between it and the outer surface of the vehicle) which act as a meteor damper, so that the outer surface of the vehicle wall would be exposed only to the weakened action of the explosion products. An approximate method is proposed in [668] for estimating the upper values of the thicknesses l_0 of the mantle and l_W of the wall, and of the magnitude h of the gap, which means that all assumptions and simplifications used in this method are on the safe side, leading to larger dimensions. It is assumed that an oncoming meteorite punctures a hole of radius r_0 in the mantle, evaporates and takes the form of a dense mass of vapor of radius r_0 and length l_0 (the same as the hole and thickness of the mantle); the vapor expands only lengthwise during the passage of the gap h. The wall thickness is determined from the condition that all the kinetic energy of the vapor is spent in vaporization of the wall material. The thickness L of a wall not protected by a mantle is determined and an expression for the ratio $(l_0 + l_W)/L$ is derived for the given h.

The selection of the most rational values of h/L, l_0, and $(l_0 + l_W)$ based on calculations is discussed, and the weight of the cover of a space vehicle in the case of an unprotected wall (L) and a mantle-protected one $(l_0 + l_W)$ are compared and the advantages of the latter are pointed out. The method can be made more exact as more knowledge on meteors and their interaction with a wall is acquired.

GROUP D. STRENGTH OF FLIGHT-VEHICLE COMPONENTS
(Thin and sandwich plates and shells)

Thin plates and shells, solid, laminated and of sandwich construction, are the most frequently used components in the construction of flight vehicles, machinery, and instruments of modern de[illegible]. Box-type spars of airplane wings, the fuselage and wing skin; the bodies of rockets, satellites and space vehicles; the membranes, diaphragms, and bellows of instruments; the cases and diaphragms of turbomachines, etc., consist of these elements or of their various combinations. The most significant role in the development of the design of these constructions is played by the theory of plates and shells, especially the works of K. Z. Galimov, A. L. Gol'denveyser, Kh. M. Mushtari, V. V. Novozhilov, V. Z. Vlasov, and of others on the thin plates and shells which are well known outside the USSR from their translations, mainly English. In this report only those publications concerning the theory of thin plates and shells will be mentioned which are associated with topics related to high-speed flight vehicles and their operation: minimum-weight design, load-carrying capacity, thermal stresses, dynamic stability, aeroelastic and aerothermodynamic problems, and liquid-filled shells. All these publications can be divided in two groups: publications dealing with static and with dynamic stress and strain analyses.

1. Static Stress and Strain Analyses

Cantilever anisotropic or orthotropic plates are often used as design models for monolithic cantilever wings or control surfaces of high-speed aircraft or winged space vehicles. The term "monolithic wing" means a wing with a thick skin which is able to resist the normal and tangential stresses varying over the skin thickness. The spars and ribs of such a wing are designed to resist only the shear forces. This type of construction is used in high-speed aircraft wings, tail units and in fins of rockets and missiles. Thin monolithic wings have lower rigidity in bending and especially in torsion thus creating serious aeroelastic problems.

a. Wing design

The general strength of a sweptback wing of monolithic construction stiffened with stringers and with ribs parallel to the fuselage axis is analyzed in [677]. The wing is under uniform continuous loading (flexural and torsional moments, and shear forces) and a concentrated load, all applied at the free end of the wing. A cantilever anisotropic plate is taken as a design model, and the stress analysis is carried

out under conventional assumptions of the small-deflection theory. The relationships between the stress and displacement components are established, and the determining of stresses in the skin is thus reduced to determining the deflections of its middle surface. The principle of virtual displacements is applied to derive approximate differential equations of the fourth order with boundary conditions for determining the deflections, from the equality $\delta U = \delta A$, where U is the potential energy of the wing and A is the work of external forces. The equations derived contain a deflection function which takes account of the rigidity of the wing, so that these equations are correct for wings with thin or thick skins. A simplified solution of these equations is obtained for "rigid" wings for which an assumption can be made that the form of the cross section is not distorted by deformation under loading. The effect of the sweepback angle and the aspect ratio on the stress distribution along the span and in the root cross section of such wings is analyzed and the results are shown in diagrams. A way of obtaining a more exact solution (with consideration of the distortion of wing cross sections) by means of the method of successive approximations is indicated.

The growing speed of flight pressed aircraft designers to use thin wing profiles, thus reducing the flexural and (mainly) torsional rigidities of the wing and making its loading and stresses more dependent on deformations. The problem of determining the stresses with the effect of deformations taken account is considerably complicated by the fact that the external loading remains unknown until the problem is completely solved. The strength of a thin elastic wing of monolithic construction with regard to the effect of deformations is analyzed in [689] under conditions and assumptions as in [677]. The problem is discussed in a static formulation, which means that an equilibrium in the process of changes in deformations and in associated external forces is considered and that the change in the lift coefficient caused by deformation is proportional to the change in the angle of attack. The mass forces are taken into account, and the interrelated stresses and deformations are determined in two cases: 1) when the angle of attack at the root cross section of the wing is prescribed (e.g., flight in gusty air); and 2) when the load factor is prescribed (flight along a given curvilinear trajectory). The design formulas for stresses and deformations are given in matrix form, which is very convenient for making calculations, especially on electronic computers.

The possibility of using these formulas for other purposes, for example, in determining the aerodynamic loads, lift and moment coefficients of an elastic wing with its deformations taken into account, is pointed out, and the divergence and aileron-reversal speeds of an elastic monolithic

wing are determined as examples of such applications.

The solutions obtained in [677] and [689] are generalized in [715] for a monolithic wing with nonparallel stringers and with ribs parallel to the plane of the root cross section. The stiffeners (stringers and ribs) are treated as flexible ropes carrying only axial loads. It is assumed that the wing elements resisting the shear forces (the skin and the webs of ribs and spars) are continuously distributed (along the span and chords respectively). An anisotropic plate is used again as the design model. Two special cases of a monolithic wing design are examined: 1) when sharp changes in loading (e.g., a concentrated load) or in the shape take place in some cross section along the span; and 2) when the wing is of a continuous type (i.e., has a central portion under the fuselage). The changes in equations and boundary conditions involved in cases (1) and (2) are discussed, and in the latter case the simplified general formulas (obtained by assuming a nondistorted cross section of the wing during its deformation as in [677]) are given. The results of computing the stress distribution and the deformation in the root cross section in following triangular wings with a 45° sweep of the leading edge and with the trailing edge perpendicular to the fuselage axis are shown in diagrams and are briefly discussed: three detachable wings with various arrangements of stringers (parallel to the trailing edge, parallel to the leading edge, and parallel to the median of the wing-tip angle); and two continuous wings with different arrangements of the central portion; both with stringers intersecting in the wing-tip corner.

The effect of nonuniformity in strength and spacing of the stringers over the depth of various wings (rectangular, sweptback, and triangular) on the stress distribution in outer fibers of the wing skin is discussed in [722] by presenting the results of theoretical stress analysis by the method given in [677] and [715]. The calculations were carried out for two patterns of stringer arrangement: 1) the effectiveness of the stiffening decreases (stringers are weaker and their spacing grows) along the chord with increasing distance from the leading edge; and 2) the stiffening pattern is inverse to that in case (1). The following types of wings were considered: a) straight wings of rectangular and double-wedge cross section constant along the span; b) sweptback wings of cross sections as in (a); c) triangular wings of rectangular cross section with various directional arrangements of stringers (as described in [715]). The variations of longitudinal stress in the root cross section are shown in diagrams and discussed as well as the displacement of the flexural axis, the additional stresses due to constrained torsion, and the dependence of the stress distribution

on the arrangement of the stringers.

The stress distribution in tapered wings is similar to that in conical shells under similar conditions. The investigation of stress-strain relationships in a sharply tapered thin-walled flattened conical shell having the shape of a tapered (in plan and thickness ratios) wing is presented in [719]. The equations for determining the deformations and stresses in the shell of constant thickness are derived in displacements and are based on the general variational method proposed by V. Z. Vlasov. This approach to the problem permits determining the stresses and strains in the shell in a simple way and with a satisfactory accuracy. The basic assumption used is that the stress distribution is uniform along the thickness of the thin shell. The longitudinal and lateral displacements of a point on the surface of a panel (between spars and adjacent ribs) which are caused by external forces are investigated, and systems of Euler-type differential equations (in terms of generalized displacements) with variable coefficients (containing the distribution functions of displacements) are derived. The extension of these equations to stringer-stiffened shells is briefly discussed.

The application of the proposed method is illustrated by deriving the design formulas for a wing-like cantilever conical shell under a lateral force at the free end and by presenting a numerical sample calculation. The systems of differential equations obtained can be applied to designing one-cell and multicell conical shells under arbitrary loading, and to determining thermal stresses due to constraints in bending and torsion.

b. Minimum-weight design

The problem of designing a structure having a minimum weight under given conditions is associated with the lower and upper estimates of limit loads for this structure by applying the yield conditions for maximum tangential stress and for maximum reduced stress, respectively. In [807] the yield condition for the maximum reduced stress is used for determining the lower limit load in designing a cylindrical shell of minimum weight under continuous uniform internal loading. The shell is of sandwich construction; the faces, of variable thickness, are of a perfectly elastic-plastic material, so that the minimum-weight and minimum-volume problems coincide; the material obeys the yield condition under maximum reduced stress and the associated flow pattern. The core, of constant thickness, is of a lightweight material. The yield behavior of a simply supported cylindrical shell is investigated, and the corresponding deflections, the variation of the face thickness along its axis, and the volume

(i.e., the weight) of the shell are determined and shown in diagrams. The volume of the variable-thickness shell is compared in a diagram with the volume of a constant-thickness shell in relation to the length of the shell.

Analogical analysis is carried out for a cylindrical shell with fixed ends. By the comparison of weights the author comes to the conclusion that a noticeable economy in weight can be achieved by using short shells.

The optimum design of a medium-long or a long shell of given thickness stiffened by annular frames of different rigidity and acted upon by external pressure is solved in [795], with the requirement that the shell must have the same stability against various modes of buckling. The method of initial parameters in matrix form is used in determining the necessary rigidity of the annular frames. The shells with one, two, and three frames are analyzed, and the author comes to the conclusion that equistability can be ensured by two methods: 1) in a case when identical rigidity of the frames is prescribed—by the selection of their proper spacing, and 2) when the spacing of the frames is uniform—by using frames of various rigidities.

Shells consisting of two layers of different materials are an important constructional element. Metallic shells with an inner or outer layer of plastics used either as thermal insulation or as ablation shielding or a protective layer against corrosion are often used in aircraft design. A cylindrical shell with an outer layer of polymeric material with a filler, exposed to the action of internal pressure and of a temperature field is discussed in [743] with the purpose of determining the state of stress in both layers and of establishing their minimum-weight relationships. The outer layer is treated as a constructionally orthotropic membrane shell stiffened by equidistant stringers and uniformly spaced prestressed rings. The inner layer is treated as a shell with bending stresses. The interaction between both layers is investigated assuming their joint deformation, and a fourth-order differential equation (containing the parameters of rigidity, pressure, and temperature) of the problem on the states of stress and strain of the shell is derived; the constants of integration of this equation can be determined from the boundary conditions and used in finding the stress distribution at the ends of the shell (the edge effect). These constants are determined for two arrangements of the bottom of the shell: 1) plane hinged bottom with a reinforced flange, and 2) semispherical bottom rigidly connected to the shell. The minimum-weight problem of this shell is solved under the assumptions that the whole shell is in a membrane-stress state (because the edge-effect zones are very narrow, only a few

shell thicknesses) and that the outer layer has only the stiffening rings. The minimum weight is determined under the condition that stresses in the layers should not exceed the prescribed limits; the thicknesses of the layers as well as the initial tension in the outer layer can be determined.

c. Load-carrying capacity

The load-carrying capacity of a structure is understood to be the value of a limit load which the construction can carry without failure or buckling under a certain loading path. The calculation of the load capacity and the investigation of the effect of certain structural parameters on the limit-load variation help to keep the weight of the structure low. In [824] an attempt is made to develop a comparatively simple method for determining the load-carrying capacity of stiffened thin-walled circular cylindrical shells under axial compression. The method is based on the assumption that the longitudinal members of a real shell with manufacturing irregularities and other deviations from the design conditions are subjected to a combination of axial and transverse loadings; the presence of stiffeners (stringers and frames) justifies treating the shell under discussion as "constructionally" orthotropic. The cases of axisymmetrical and of axially asymmetrical initial imperfections of the shell are discussed. In the former case, formulas for the critical (failure) stresses in stringers and frames are derived. Either the buckling stress in certain elements of a stiffener or the yield stress of the material (whichever is lower) is taken as the critical stress. In the axially asymmetrical case, an analogous procedure is used, and similar expressions for critical stresses are obtained. The discussion of the effect of the internal pressure in cases of both symmetrical and asymmetrical initial irregularities on the load-carrying capacity of a constructionally orthotropic cylindrical shell leads to the conclusion that the internal pressure can increase the load capacity in an asymmetrical case when the circular frames are relatively weak or when only stringers are used.

The load-carrying capacity of a plain cylindrical shell under pure flexure is discussed in [826]. An attempt is made to obtain a physically convincing and simple mathematical solution of the failure problem based on geometrically linear theory and to define more exactly certain principles concerning the buckling of the shell. The load-carrying capacity of the shell is determined from the conditions of strength and of buckling of the shell. The strength of a plane cylindrical shell under pure flexure and external uniform radial pressure is analyzed under the assumption that the load capacity will be exhausted when the total stresses at a certain

point exceed the yield stress of the material. The formula for determining the load-carrying capacity of the shell with respect to its strength is derived, and the results of calculation are compared in a diagram with experimental data obtained by other authors. The load capacity of the shell with respect to local buckling is also analyzed, and it is shown that the presence of radial pressure decreases the critical (failure) stress in the shell. A practical formula for determining the real critical stress is given. Fair agreement of the theoretical values with experimental data can be seen in the above mentioned diagram. The coincidence between theoretical and experimental results in determining the load capacity with respect to both strength and buckling as well as the different character of the discrepancies in the buckling behavior of shells under flexure and under pressure are examined in more detail, and the feasibility of extending this study to constructionally orthotropic, i.e., stiffened, shells is mentioned.

A general solution of the problem of the rigidity of cylindrical shells having frames at the ends and several frames arbitrarily spaced between them is presented in [827]. The effect of the spacing of an arbitrary number of intermediate frames on the strength, buckling, and free vibration of a cylindrical shell is investigated under the assumption that these frames are elastic in their planes but perfectly pliable in the out-of-plane direction; the end frames can be either rigid or elastic. In solving this combined variational problem, the radial displacements W are taken as an unknown function and the hoop stresses, bending moments, shear forces, and the potential of external forces are considered in writing the energy functional for a section of the shell between the frames. By minimizing this functional, a fourth-order differential equation with boundary conditions is derived from which the general solution (an expression for W) is obtained. By using proper boundary conditions the solutions for either the fixed, simply supported, or free ends of the shell can be derived. The adaptation of the general solution in the following particular cases is discussed: 1) the strength under axisymmetrical loading; 2) the axisymmetrical mode of shell buckling; 3) the shell under lateral flexure combined with axial compression; and 4) axisymmetrical free vibration of the shell.

The buckling behavior of a shallow oblong cylindrical panel with longitudinal ribs (which are hinged to the shell) subjected to a uniform normal pressure is investigated in [794]. The pressure is $q(t) = Mq + \xi(t)$, where the pressure function Mq = const, and $\xi(t)$ is a time function describing a random stationary process. The presence of disturbances $\xi(t)$ causes the crossing of the potential barrier of the panel

and thus its premature (from the viewpoint of the classical stability theory of elastic systems) buckling at a certain random instant t. From the numerical characteristics of t one can make a judgement about the load-carrying capacity of the panel. It is assumed that $\xi(t)$ has a wide-band character, i.e., its correlation time is small in comparison with the natural frequency of the panel, as it is in the case of real disturbances of acoustic or aerodynamic origin. Equations previously derived by the author (under the assumption that the deflection and its first time derivative describe a Markoff process) are used in determining an expression for the mean time of buckling from which a qualitative estimate of the load-carrying capacity can be made.

The problem of the stability of circular cylindrical shells under axial compression forces nonuniformly distributed along the edges of their faces has been studied by many authors with satisfactory results. But the effect of nonuniformity in the distribution of compressive forces on the amplitude of the critical (buckling) stresses is insufficiently known, and considerable discrepancies exist between values of stress factors accounting for this nonuniformity. The linear problem of the local stability of a circular cylindrical shell with its faces abutting on rigid diaphragms and subjected to compressive loading, which varies according to the cosine law, in the middle surface of the shell is investigated in [809] with the purpose of comparing the values of buckling stresses under nonuniformly and uniformly distributed loadings. The procedure in deriving a formula for local deflections is outlined, and the results of the computation of relationships between certain buckling parameters are presented in diagrams. By analyzing these relationships, the author comes to the conclusion that nonuniformity in the distribution of compressive loading has no influence on the magnitude of the buckling stresses. Local buckling is analyzed in the example of a long cylindrical shell placed in a high-temperature field and partly filled with zero-temperature liquid, so that a temperature jump which causes thermal stresses takes place in the circumferential direction. Expressions for the buckling temperature and associated critical compressive stresses are derived, and the calculated values of the buckling stresses are practically the same as those obtained for the same shells under uniformly distributed compressive loading.

d. Thermal stresses and buckling

Temperature changes in the surrounding medium cause volume changes in bodies placed in this medium which result in a state of stress and strain. The magnitude of these stresses and strains must be kept within certain bounds in order to prevent thermal failure of the body. Establishing

temperature-dependent stress-strain relationships and determining thermal stresses and strains is the purpose of many studies published in the Communist World, the most characteristic of which will be mentioned.

The behavior of a heated orthotropic plate is investigated in [758] by taking into account the shear stresses $\tau_{xz} = [f_1(z), \varphi(x, y)]$ and $\tau_{yz} = [f_2(z), \psi(x, y)]$ according to the S. A. Ambartsumyan theory of anisotropic shells, and assuming that the relative deformation over the thickness of the plate e_z is given by the free thermal expansion in that direction $e_z = \beta_z T$, where $\varphi(x, y)$ and $\psi(x, y)$ are the unknown functions, $f_1(z)$ and $f_2(z)$ are the given functions determining the pattern of variation of τ_{xz} and τ_{yz} along the plate thickness, β_z is the coefficient of thermal expansion along z, and T is the temperature. The elasticity and shear moduli, Poisson's ratio, and β are the given functions of T. The origin of the coordinate axes is in a corner of the plate with the z-axis along the plate thickness. Starting with the integration with respect to z of the differential equation of equilibrium of a plate element, a solving system of five differential equations with variable coefficients is obtained for determining the three displacement components and the functions $\varphi(x, y)$ and $\psi(x, y)$. The application of these equations to the following particular cases is shown: 1) when T varies only along the z-axis; 2) when T varies along the x- and y-axes; and 3) cylindrical flexure of the plate. A sample analysis of stresses in a case when the temperature is zero under the plate and changes linearly from zero to 400°C on the upper surface is carried out for a plate with two opposite sides clamped, and the considerable effect of transverse shear stresses on the magnitude of the resulting forces and moments is pointed out.

The buckling behavior of plates and shells in a supersonic gas flow was examined many times and the determining parameters obtained were mostly established in relation to the initial (prebuckling) state of these structures. But in solving the problem of the thermal buckling of plates and shells in a gas flow, their stability in the buckled state is of most interest. The behavior of plates and shells under the postbuckling conditions is discussed in [741] by using the published data on flight conditions of the V-2 rocket, and it is shown that under these conditions the thermal buckling is a prevalent factor in failure at high temperatures. The equations describing the vibration of plates and shallow cylindrical shells under conventional assumptions (validity of Kirchoff-Love hypothesis, comparability of deflections with the thickness, given temperature fields, etc.) are brought to a nondimensional form, and a system of determining parameters (temperature, pressure, structural damping, velocity,

etc.) are brought to a nondimensional form, and a system of determining parameters (temperature, pressure, structural damping, velocity, etc.) is discussed and selected. Only the temperature parameter θ and velocity parameter μ are considered in the study of the postbuckling behavior of a cylindrical shallow shell of a rectangular planform with supersonic gas flow on the outer surface along the directrix. It is shown that the shell undergoes either thermal buckling or flutter and that the cause of failure depends on the relation between θ and μ. The calculated values of these parameters for various length-to-thickness ratios a/h of the shell are plotted in (θ, μ) coordinates, and the regions of stability, flutter, and thermal buckling are determined (Fig. 12). The conclusion is reached that the problem of thermal buckling of shallow shells in high-speed gas flows deserves perhaps not less, but more attention than the problem of flutter.

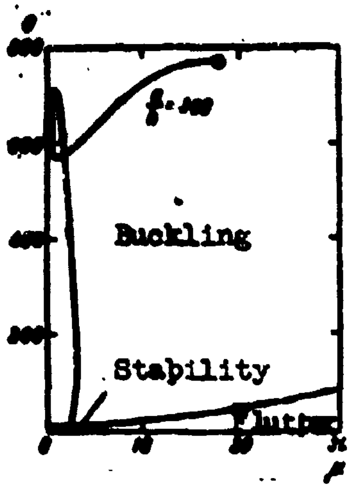

Fig. 12

The assumption usually accepted at lower temperatures that the physical properties of materials are independent of the temperature is inadmissible in designing modern flight-vehicle structures, where the gradients of temperature fields are high and grow with the increasing kinetic heating due to increasing speed of flight. The large temperature gradients compel consideration of the dependence of elastic constants and thermal expansion coefficients of materials on the temperature in determining the thermal stress and strain distributions, as well as in solving other thermoelastic problems. An analysis of thermal stress-strain relationships in an orthotropic shell of revolution with consideration of the time-dependent physical properties of its material is presented in [742] in linear formulation, disregarding creep, and assuming the validity of the generalized Hooke's law. The usual assumptions (on preservation of normals, free thermal expansion over thickness, negligibly small thickness-to-radius ratio, etc.) are applied in deriving a system of linear differential equations and of formulas for determining the forces and displacements in the meridional, circumferential, and normal-to-surface directions, as well as the moments in the meridional and transverse planes. The integration of the equations is impossible in the general case; therefore, these equations are rewritten for particular shells of revolution (cylindrical, conical, and spherical) and for a circular plate. There is a detailed discussion of the thermal problem of a cylindrical shell of revolution in the case when the temperature varies linearly along its length, Young's modulus varies linearly with the temperature, and Poisson's ratio is independent of the temperature.

The skin of a stiffened shell moving at high speed in the air is considerably heated whereas the inner stiffening members remain cool and hinder the thermal expansion of the skin, thus creating compression stresses in the skin and tension stresses in the inner members, so that buckling of the skin can occur. The thermal stability of an orthotropic circular cylindrical shell in an external temperature field is discussed in [804] under the assumption that the induced thermal stresses in the skin are constant along the length of the shell and across the thickness of the skin and vary over the circumference. This simplification of the original problem reduces the problem of thermal stability of a shell to that of its static stability under proper boundary conditions.

Fundamental equilibrium equations for an orthotropic cylindrical shell in terms of displacements are derived in general form assuming a membrane state of stress prior to buckling. These equations are used in determining the stability of a simply supported cylindrical shell by selecting the corresponding boundary conditions, and an infinite linear system of algebraic equations is obtained. By equating the determinant of this system (the stability determinant) to zero, a general solution can be obtained by a complicated procedure, which can be greatly simplified for particular loadings. Simple design formulas for the buckling stresses in orthotropic and isotropic cylindrical shells under axial compression and for orthotropic shells under flexure are derived.

By the nonuniform heating of long cylindrical shells in the circumferential direction, longitudinal stresses which can cause their buckling are originated in their middle surface. The clarification of the effect of nonuniformity in the thermal stress distribution on the magnitude of the buckling stresses needs supplementary studies. The local buckling of a circular cylindrical shell under the above conditions is investigated in [762] as a linear problem. Starting with the stability equations and taking the unknown functions in them in the form of trigonometric series, an infinite system of homogeneous equations is obtained in matrix form, thus reducing the problem of determining the buckling stress to determining the maximum eigenvalue of the matrix (by the iteration method); the eigenvector of the matrix will determine the deflections. A case of practical importance is the stability of a cylindrical shell in the horizontal position partly filled with a zero-temperature liquid and placed in a medium with a higher (lower) temperature corresponding to heating (cooling) of the liquid. The buckling behavior of the shell, the buckling temperature of the medium, and the effect of the level of liquid in the shell are discussed and

illustrated by diagrams. It is shown that the investigated nonuniformity in stress distribution has practically no effect on the magnitude of the local buckling stress.

e. Sandwich constructions

Plates and shells of sandwich construction are extensively used in aircraft design (lifting surfaces, fuselage) not only for their higher load-to-weight ratio but also for their heat- and sound-insulating and vibration-damping properties. The stress analysis of the sandwich plates and shells under various external loadings and boundary conditions is a topic often discussed in Soviet technical scientific literature; the buckling behavior of sandwich plates and shells is discussed less often. The skin of a wing of sandwich construction is subject to aerodynamic heating in high-speed flight; the outer face of the sandwich skin is heated much more than the inner face, and thermal stresses occur. The effect of thermal stresses on the buckling of a sandwich wing panel of the upper airfoil surface between adjacent spars and ribs is investigated (according to the author, for the first time) in [718]; the panel is compressed in the longitudinal direction by uniformly distributed forces along the ribs and is clamped along all sides. The following assumptions are made: 1) the compressive loading is carried by the face layers only; 2) the hypothesis of straight normals is valid for the face layers; 3) the core layer is free of stresses up to the instant of buckling; and 4) thermal stresses and strains in the core are disregarded because of its low rigidity. The thermal stresses and their distribution in face layers are determined as well as the states of resulting stresses in them, and the equilibrium equations for both face layers are derived. The expressions describing the stress distribution in the core and the joint deformation of all three layers are derived, and from them the expression for the buckling force is deduced. The effect of distribution of thermal stresses on the magnitude of the buckling force is discussed.

The flexure of an unsymmetrical sandwich plate with a rigid isotropic core and unequally thick faces made of different materials subjected to transverse loading combined with nonuniform heating is examined in [797]. It is assumed that the temperature and displacements vary linearly over the thickness of the core (the least heat conductive of all layers), and that the Kirchhoff-Love hypothesis is valid for the face layers; the transverse compressibility of the core is neglected. The differential equations of small deflections with boundary conditions are used in investigating the flexure of a simply supported plate (Fig. 13) under transverse loading q, compression forces P, and thermal loading t linearly distributed along both faces (linear heat source along the x-axis inde-

pendent of the y-axis). The flexure of the plate (by the bending moments distributed along the edges parallel to the x-axis) occurs when the forces in the middle surfaces of the face layers are of opposite signs (tension and compression); an expression for the deflection function under this loading is derived. A formula for deflection in the case when the plate is subjected only to transverse loading is deduced. A solution is also given for the case when two opposite edges are clamped and two others are simply supported.

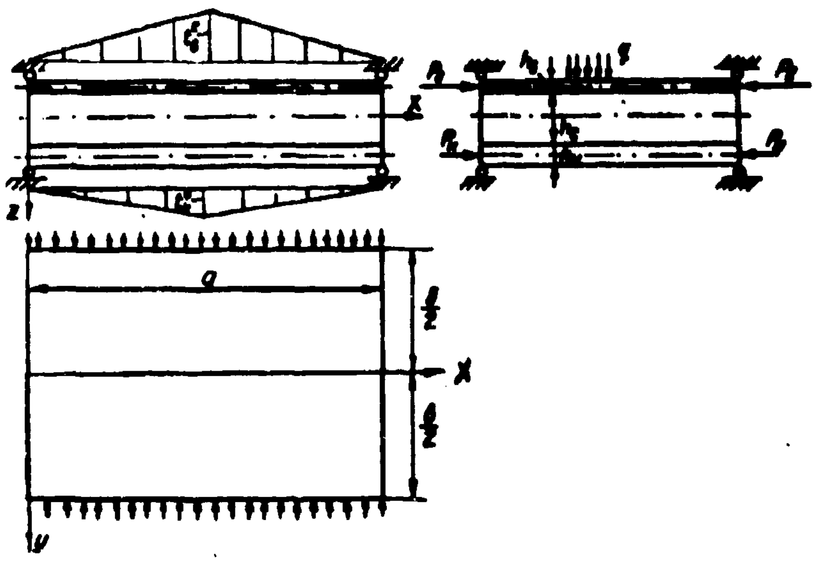

Fig. 13

2. Dynamic Stress and Strain Analyses

a. Vibration and flutter

Thin plates and shells which are structural components of flight vehicles are exposed to the action of aerodynamic forces which cause such undesired phenomena as buffeting, vibration, and flutter, which can produce, in turn, the buckling and failure of these elements. Because of the increasing speed of flight, the dynamic behavior of plates and shells in a high-speed flow of a compressible gas is a more and more frequently discussed topic in Soviet-Bloc technical scientific literature. Publications dealing with the flutter and vibration will be mentioned.

The dynamic stability of plates and shells has been studied mostly in the linear formulation, and the problems associated with relatively low speeds (e.g. the lower flutter speed of a panel) can be treated by means of linear theory. At higher speeds, the deviations from linearity in relation-

ships between geometric and flow parameters force the investigator to use the concepts of nonlinear theory. The study of the nonlinear flutter of plane and curved panels in very high supersonic flows is presented in [696], with stretching of the middle surface and thermal buckling caused by kinetic heating taken into account; the effect of joint deformation of the panel together with the whole structure (the effect of clamping) on the boundary conditions is considered. The flutter of a double-curvature shallow panel of rectangular planform in a supersonic gas flow (parallel to its longer side) on its convex surface is investigated. The plate is surrounded by a steady temperature field generated by the kinetic heating, with a gradient linearly varying over the thickness of the panel, and arbitrarily varying over its middle surface. The basic assumptions of the nonlinear theory of shallow shells (the validity of the Kirchhoff-Love hypothesis, the comparability of deflections with the shell thickness, and their smallness in comparison with its dimensions) are accepted. The flutter motions are assumed to be so slow that the tangential inertia forces can be neglected, and only the normal ones to be considered. A system of differential equations describing the flutter behavior of the panel under the thermal and normal loading (which consists of inertial and damping forces and aerodynamic pressure) is solved by making simplifying assumptions and introducing nondimensional parameters; approximate expressions are derived for determining the flutter speed, and estimating the amplitudes of oscillation and the normal stresses at speeds higher than the speed of flutter. The conditions for the "soft" and "hard" flutter, as well as the interdependence of the flutter speed, amplitudes, and stresses for various thickness-to-length ratios of the panel are discussed and illustrated by diagrams.

In investigations of the oscillatory motion of a wing at high supersonic speeds, the nonlinear interdependence of aerodynamic forces and the angle of attack has to be considered. At high hypersonic speeds of flight the time $\tau = b/v$ (where b is the chord, v, the speed) will be negligibly small in comparison with the oscillation period T, and the ratio τ/T (proportional to the Strouhal number) will be very close to zero. In [756], it is shown that under these conditions the data about flutter obtained by the stationary theory in a case when the angle of attack is constant with respect to time can be applied in a case when the variation of the angle of attack is caused by oscillation. The results of the study of the flexural-torsional flutter of a wing by this simplified method with the aid of an MN-7-type electronic analogue computer are presented. The dependence of the flutter speed on the wing parameters and on the initial disturbances (e.g., wind gusts, atmospheric turbulence) is established; the effect

of the fuselage on the flutter speed is also considered. The results are discussed and illustrated by diagrams.

The unsteady flutter of plates and shallow shells in a supersonic gas flow is analyzed in [751]. A method previously developed by the author is applied in setting up a system of equations describing the dynamic behavior of plates and shells in a supersonic gas flow and thus surrounded by a temperature field; the characteristic temperature of the plate (shell) and the velocity of the undisturbed flow are described by parameters θ and μ respectively, so that a point in the (θ, μ) plane gives an idea of the conditions of the plate (shell) surroundings in time-variable fields of temperatures, velocities, and pressures. This fact is used in determining the character of the transition to flutter and the associated values of the temperature and velocity parameters. An approximate method, developed by N. N. Bogolyubov and Yu. A. Mitropol'skiy, for investigation of transient processes in nonlinear systems with many degrees of freedom is used in searching for nonstationary solutions in cases of simultaneous changes in parameters of flow velocity, density, and pressure in the surrounding medium, and in the temperature of the plate (shell). A (θ, μ) diagram plotted from calculated values which illustrates the loss of stability of a plate is shown in Fig. 14. The crossing of the line AF means the loss of stability through the flutter, and of the line DF, through the thermal buckling. Equations for determining the frequency, amplitude, and phase of a nonstationary flutter are derived, and their application is discussed. An example of calculating the flutter parameters for a plane nonheated plate is presented, and the results obtained are examined and illustrated by diagrams.

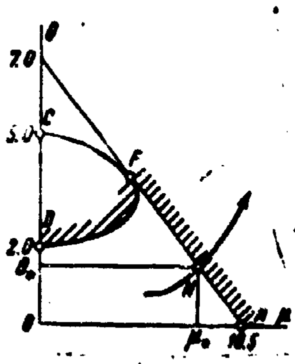

Fig. 14

Knowledge of the modes of free vibrations of aircraft elements and of their natural frequencies is necessary in investigating oscillatory problems. The vibration parameters of lifting surfaces are of special importance because of the high speeds at which they operate when used on modern airplanes, guided missiles, rockets, etc. They are usually of monolithic construction (see above, D-1), and a cantilever plate is used as a design model for them. The modes and frequencies of free vibration of the most general type cantilever plate, anisotropic, laminated, swept-back, tapered, with arbitrarily variable thickness along the span and chord, are investigated in [684]. The plate simulates a thin monolithic wing or tail unit with a thick skin stiffened by stringers and rib flanges. The Ritz method is used for determining the modes of free vibration along the span (for a given vibration mode along the chord) using the equations in

matrix form, so that the problem is reduced to determining the eigenvalues and eigenvectors of a special dynamic matrix whose elements depend on rigidity and inertial characteristics of the construction. The method is very convenient for use on electronic digital computers. The flexural and torsional free vibrations are analysed by using the hypothesis on the nonvariability of the cross sections of the wing under vibration, and the results are compared in a table with the data of investigations where this hypothesis was not used and with experimental data. A fair agreement among all these results is demonstrated. The possibility of replacing the swept-back plate by an equivalent straight plate is discussed.

In solving certain dynamic problems in aircraft design it is sometimes necessary to investigate the vibration of thin-walled structural members of thin-plate and thin-shell types exposed to a high-frequency excitation. For determining the modes of vibration asymptotic expressions can be derived which can be used in any region except in those adjoining the reinforced contour, at abruptly changing cross sections, etc., where the distortion of the dynamic stress field, the phenomenon called "dynamic edge effect," takes place. It is known from experience that the fatigue failure of vibrating thin-walled structures begins in these "distorted" regions. Therefore, solutions are sought which satisfy the "distorted" boundary conditions and tend to asymptotic expressions for vibration modes in inner regions not too close to the edges. The theory of the dynamic edge effect in the vibration of elastic shells is presented in [707] with an analysis and classification of various types of the edge effect for shells of positive, zero, and negative Gaussian curvatures; methods are given for calculating the edge-effect characteristics in the distorted-stress regions from the known solution for the inner regions. The equations of shell theory (derived by A. L. Gol'denveyzer) describing the modes of vibration in states of stress with a large index of variation (large wave number) are used to derive an expression which completely determines the properties of the dynamic edge effect in the case of vibration with given wave numbers. This expression is used in deducing formulas for the dynamic edge effect in plates, shallow shells, and spherical shells, and it is generalized (by introducing nondimensional parameters) to discuss the conditions of existence of an edge effect and its degeneration and to determine its type. The application of the proposed theory to investigating the frequency spectrum and modes of natural vibration of a spherical panel is given; the panel is clamped along a contour bounded by four orthogonal lines of curvature (Fig. 15). It is shown

Fig. 15

that the tangential displacements along the lines x_2 = const and x_1 = const do not affect the normal deflections, and the asymptotic estimates of natural frequencies and wave numbers are obtained in a simple way. Results of computations in the case when a = b are given in a table and are compared with those of a very accurate and laborious calculation by S. Iguchi; the results are almost identical.

b. Liquid-filled shells

The solution of problems of dynamic stability of space vehicles during launching and in motion when either the direction or the speed of flight, or both, are changed (e.g., corrections of the orbit, deceleration) boils down to the investigation of the disturbed motion of a solid with cavities partly or completely filled with a liquid. The oscillation of fuel in tanks is excited by vibration of the tank itself and of other structural and control elements of the vehicle, so that the problem of dynamic stability of the body-liquid system arises. These problems are usually solved by variational methods which permit a convenient use of computers. A systematic presentation of variational principles and their substantiation in analyzing the oscillatory behavior of liquid-filled bodies is given in [787]; the body is either rigid, or elastic and obeying the hypothesis of preservation of plain cross sections. The oscillation of the liquid in a fixed open vessel is preliminarily discussed. The application of the Ritz method is described; oscillation of a conservative system of bodies, some of them having cavities filled with a perfect, incompressible liquid without vortices is analyzed; and the static stability of the system is investigated. An approximate method of determining the free oscillation of the body-liquid system is given. The torsional, flexural, and combined free vibrations of an elastic beam with a cavity filled completely or partially by a liquid are discussed, and formulas for natural frequencies are derived. The stability of the beam-liquid system is investigated, and the analytical conditions of stability are formulated. The advantage of the variational method used in this investigation is stressed; it is convenient for the use with electronic computers and makes standardized programming possible.

The dynamic behavior of stiffened thin elastic shells filled with a perfect incompressible liquid is analyzed in [788]. The study is based on A. M. Lyapunov's works on the stability of motion of mechanical systems, and on works by V. V. Bolotin about the dynamic stability of elastic systems, particularly of shells. The works by V. V. Novozhilov, Kh. M. Mushtari, and V. Z. Vlasov on thin shells are also used. The variational equations of motion of the shell-liquid system under the action of arbitrary time-variable forces acting upon

the shell surface are derived under the assumptions that the stiffeners possess flexural rigidity only in the direction normal to the shell surface and rigidity in tension (compression), and that the connection between the skin and stiffeners is strong enough to ensure their joint deformation. From these equations the differential equations which describe the dynamic stability of the system are derived under the assumption that the liquid does not separate from the shell (coincidence of the normal velocity components of both liquid and shell over the surface of their contact). The following problems of the stability of a cylindrical shell with liquid are examined, and the stability parameters (amplitude and frequency of oscillation, pressure, critical forces and stresses) are discussed: dynamic stability of a plain closed shell; quasi-static stability of a completely filled shell and of a shell stiffened by closely spaced stringers; shells stiffened by discretely spaced circular frames; dynamic stability of a closed shell stiffened by stringers. Possible simplifications of the proposed method are discussed.

When the cavity in a body is almost completely filled with liquid, a bubble of air of almost spherical shape is formed, and the dynamic problem consists in determining the motion of the liquid and that of the bubble in the cavity, and in describing the motion of the body. The discussion of this problem is presented in [845] under the assumptions that the following conditions are fulfilled (and it is so for many liquids, including water): $va \gg \mu/\rho$ and $v^2a \gg \sigma/\rho$ (where a is the radius of the bubble; ρ and μ are the density and viscosity of the liquid, respectively; σ is the coefficient of the surface tension on the interface between the liquid and bubble; and v is a characteristic value of the liquid velocity relative to the cavity); and that the bubble is a nondeformable sphere and the liquid is a perfect one. The equations of motion of the body-liquid-bubble system containing its momentum Q, kinetic energy T, and kinetic moment K, and the expression for the potential energy Π of the liquid are used as the initial ones. These equations are solved first as if the liquid filled the cavity completely (determining thus the parameters of the motion of the body-liquid system); then, by integrating the equation of motion of the bubble, the coordinates and velocities of its center are determined. By substituting these quantities in the initial equations of motion, the parameters of the motion of the body-liquid-bubble system are determined. The following particular cases are examined: 1) the liquid (without a bubble) performs a translatory motion; this can happen when the body is in translation or if the cavity is a sphere; and 2) the body with liquid and bubble is subject to an impact so that all parameters change suddenly and Q, T, and K receive finite increments. Under these conditions, the deformation

of the bubble is taken into account and it is proven that this consideration has no effect on the increase of the kinetic energy. Formulas for determining the behavior of the system under impact are derived. The instability of the positional equilibrium of the bubble in the steady potential flow of a perfect incompressible liquid is discussed.

The consideration of the surface tension of the liquid in solving the problem of motion of a body with a cavity filled with liquid plays an essential role under conditions of weightlessness. The stability of motion of a liquid-filled solid and of its equilibrium with the surface tension of the liquid taken into account is discussed in [846]. The cavity is completely filled with two homogeneous incompressible, immiscible, perfect liquids possessing surface tension and subjected to mass forces. The cavity has no protruding elements (e.g. ribs) in the neighborhood of the line where the interface of both liquids contacts the wall of the cavity. The formulation of the problem also covers the cases when one liquid is surrounded by the other one and does not touch the wall, and when the cavity is partly filled by only one liquid, with air under pressure or vacuum above it. The equations of motion of the system and the boundary conditions (in which the presence of the surface-tension forces on the interface of both liquids is considered) are derived by applying the principle of least action in the Hamilton-Ostrogradskiy form. It is shown that under the conditions discussed, the total mechanical energy of the system (kinetic energies of the solid and liquid, potential energy of external forces, and surface energy of the liquid) is constant during the motion. Differential equations describing the shape of the interface of liquids in equilibrium or steady motion are derived (assuming a continuity in the motions of the body and of the liquid), and the form of the interface in the cases mentioned above is discussed. The stability of the equilibrium or of the steady motion of a body-liquid system is analyzed and stability criteria for equilibrium, steady motion, and relative equilibrium (in uniform rotation) of the system are derived. The validity of these criteria in cases of a viscous liquid (with and without surface tension) is proven.

The nonlinear problem of the oscillation of a perfect incompressible liquid in a vessel of finite dimensions under the action of gravity and surface-tension forces is presented in [847] in variational formulation, which permits the use of direct methods in its solution. The liquid fills a part of the vessel, and the rest is occupied by gas, so that coefficients of surface tension on the gas-vessel, liquid-vessel, and gas-liquid interfaces are distinguished. The gas over the liquid is assumed to be at rest, and its mass is neglected. The Hamiltonian principle for real motions is applied to the

solution of the problem, using the Lagrangian function $L = T - \Pi$ (where T and Π are the kinetic and potential energies of the vessel-liquid-gas system) and the Hamiltonian integral of action

$$J = \int_0^t L dt,$$

which assumes a stationary value, i.e., $\delta J = 0$. The problem of determining the motion parameters of the liquid can thus have a variational formulation, the problem being to find among the functions satisfying the boundary conditions those which also satisfy the condition $\delta J = 0$. It is proven that this formulation is equivalent to the conventional formulation of the problem of the motion of a perfect incompressible liquid in a fixed vessel under the action of gravity and surface-tension forces. Examples of finding the functions satisfying the condition $\delta J = 0$ in particular cases of motion and equilibrium of a liquid in a vessel of finite dimensions are given.

Concluding Remarks

As can be seen from both the annotated bibliography and the comprehensive report, the Communist-World scientific technical literature in the fields closely related to the reentry problem is very rich. Especially, the aerodynamic heating, ablation, and ablation shielding of space vehicles, their flight dynamics and control, and the dynamics of liquid filled bodies are fields of space science very intensively studied by Communist-World scientists.

The mathematical methods utilized in the investigations in these fields are so selected that they can be adapted easily for calculation on high-speed electronic computers which are widely used in the USSR.

SPACECRAFT UTILIZING THE LIFTING REENTRY TECHNIQUE

PART II

Section II - Annotated Bibliography

ATD Work Assignment No. 52
(Report no. 1 in this series)

SECTION II

ANNOTATED BIBLIOGRAPHY

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9. Frankl', F. I. Shock-wave formation in subsonic flows with local supersonic velocities. — ~~PMMe~~ v. 11, no. 1 199-202

10. Khristyanovich, S. A. Approximate integration of supersonic-flow equations. — PMMe v. 11, no. 2 215-222

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14. Khristyanovich, S. A. Shock wave at a large distance from the point of explosion.

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16. Il'yushin, A. A. The law of plane sections in the aerodynamics of high supersonic speeds.

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On the basis of Prandtl's theory, boundary-layer equations are obtained which differ from Prandtl's equations by additional terms containing higher-order derivatives of velocity and temperature. In these equations, the normal pressure gradient is distinct from zero and is expressed through additional terms. The applicability range of these equations as related to velocities and altitudes is given.

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38. Munshtukov, D. A. The hydraulic analogy for unsteady motions of liquids and gases. | IzVUZ-AvT no. 2 20-28

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Transonic motions of an ideal gas which are represented in the velocity hodograph by a curve or by a surface are analyzed. A class of self-similar solutions representing plane and axially symmetric flows is given.

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Exact discontinuous solutions are derived for the equations of one-dimensional unsteady motion of an ideal gas in the presence of shock waves.

44. Kopylov, G. N. (Leningrad). On similarity of transonic plane flows. PMMe v. 22, no. 3 391-395

A simplification of the basic equations of motion is given, based on the assumptions that the Mach number of the upstream flow is close to unity, velocities of the flow are slightly different from the upstream velocity, and the direction of the velocity vector is only slightly different from the direction of flow away from the body.

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47. Ryzhov, O. S., and S. A. Khristianovich. Nonlinear reflection of weak shock waves. PMMe v. 22, no. 5 586-599

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An approximate solution of the problem of an axisymmetric turbulent boundary layer on concave and convex surfaces is given, taking into account the longitudinal pressure gradient and the transverse surface curvature.

50. Rozin, L. A. (Leningrad). An approximate method for calculating nonstationary turbulent boundary layer in an incompressible fluid. PMMe v. 22, no. 6 842-847

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51. Barglazan, A., and O. Popa. A contribution to the theory of turbulence over a thin profile. — StuCeMeAp Jan-Jun 58 57-71

A method is developed for determining vortex distribution over a thin profile, applicable to the case of an arbitrary thin profile, without introducing any limitations on curvature or angle of attack.

52. Golitsyn, G. S. (Institute of Atmospheric Physics, AS USSR), and K. P. Stanyukovich (Moscow State University). Some remarks on the structure of shock waves. — ZhETF v. 35, no. 3 828-830

A qualitative investigation of some aspects of the physical structure of a normal shock wave in magnetohydrodynamics is presented.

53. Shkadov, V. Ya. (Moscow State University). Integration of boundary-layer equations. — 1959 DAN SSSR v. 126, no. 4 730-732

The development of a method used to reduce the calculation of boundary layers described by partial nonlinear differential equations to the solution of boundary problems for ordinary linear differential equations is given.

54. Biybosunov, I. An example of plane-parallel transonic gas flow with a curved shock wave ending in a flow with a stream function of the form $\Phi_{2/3} = \rho^{2/3} f_{2/3}(\theta/\rho)$. — DAN SSSR v. 126, no. 5 951-952

An example of transonic gas flow with a shock wave, with supersonic speed being converted to subsonic and ending in the stream function cited in the title is presented. This example is an extension of an example previously cited by F. I. Frankl' (Frankl', F. I., IVUZ, Matematika, no. 2, 1959). The solution is obtained by the method of characteristics and gives the coordinates of the shock, of the zero flow line from the end of the shock downstream, and the sonic line.

55. Ryazanov, Ye. V. Examples of exact solutions for the propagation of explosion waves in a gravitating gas with zero temperature gradient. — DAN SSSR v. 126, no. 5 955-957

The work presented in this article is a continuation of the formulations of self-similar problems and exact solutions of equations describing unsteady adiabatic motions of gas stellar models (explosions and dynamic disruption of equilibrium) previously given by L. I. Sedov. Analogous exact solutions are given here for the propagation of explosion waves in a perfect gas with its own gravitational field (with spherical symmetry) under the assumption of absence of temperature gradients.

56. Galin, G. Ya. Shock wave theory. — DAN SSSR v. 127, no. 1 55-58

This article deals with the problem of whether the equation of motion used in theoretical studies of the structure and width of a shock front, with viscosity and heat conductivity taken into account, has a continuous solution in the case of media with an arbitrary equation of state and the consequences stemming from regarding shock transitions as the limit of these solutions.

57. Lyubimov, G. A. High supersonic flows of a non-ideal gas around bodies. — IzAN MeMa no. 1 173-178

The small-parameter method developed for an ideal gas is extended to the case of non-ideal gas flows around plane contours and bodies of revolution when the internal energy of the gas is an arbitrary function of the pressure and the temperature. The application of this method to flow of air around a cone is used as an example.

58. Lyakhov, G. M. (Moscow), and N. I. Polyakova (Moscow). An approximate method for analysis of shock waves and their interactions. — IzAN MeMa no. 2 13-18

The method proposed is based on replacing the pressure-volume curve by a broken line consisting of linear segments. Expressions are derived which determine the motion of the wave front and the flow behind the wave in these sections. The application of the method to incident and reflected shock waves is discussed.

59. Churikov, F. S. On a form of supersonic gas-flow equations. — IzAN MeMa no. 3 204-207

It is shown that various linearized gas-dynamics and other equations of mathematical physics can be transformed into "compact" equations (partial differential equations having only one mixed derivative) if the initial and boundary conditions are transformed accordingly. The advantages associated with integration of "compact" equations are pointed out.

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The parameters of the asymptotic boundary layer on an infinite porous plate in an unsteady compressible flow with uniform suction over the whole plate is discussed.

61. Frankl', F. I. (Kabardino-Balkarskiy University). A new example of a plane-parallel transonic flow with a straight compressibility jump terminating in the flow. — IzVUZ M no. 2 244-246

62. **Pol'skiy, N. I. Self-similar solutions of equations for the laminar boundary layer in an incompressible liquid with heat exchange.** IzVUZ AvT no. 3 13-15

The results of finding all the self-similar solutions by direct application of methods elaborated by Pol'skiy, A. Sh. Dorfman, and P. N. Romanenko are presented.

63. **Adamskiy, V. B., and N. A. Popov.** A gas motion caused by pressure on the piston varying according to a power law. PMMe v. 23, no. 3 564-573

An integro-differential equation is derived for plane motion of a gas produced by a power-law-variable pressure on the piston. The same equation describes the motion caused by a short impact. An expansion is found which serves as a good approximate solution of this problem. Self-similar solutions of the problem and the behavior of hydrodynamic variables close to the piston are discussed.

64. Pashchenko, N. T. Flow of a highly rarefied gas past oscillating surface. PMMe v. 23, no. 4 760-765

The total force acting on a unit of a surface of a body in a translational motion and performing small transient movements is determined as well as the pressure, friction, et cetera, caused by the components of this force. The application of the free-molecule-flow method to analyze the flow past surfaces with concavities is discussed and limitations on the shape and motion of such surfaces are obtained.

65. **Zhigulev, V. N., and Yu. L. Zhilin. Bodies with minimal wave drag.** PMMe v. 23, no. 6 1019-1029

Some variational problems for bodies with minimum drag at supersonic velocities are investigated. A method proposed by A. A. Nikol'skiy is used for determining optimum body shape.

66. **Zysina-Molozhen, L. M. (Central Scientific Research Institute of Boilers and Turbines, Leningrad.). A study of a longitudinal pressure gradient on the development of a boundary layer.** ZhETF v. 29, no. 4 637-639

An experimental investigation for positive and negative values of the longitudinal pressure gradient is reported. Studies were made for ten pressure patterns along the surface over which the flow occurred.

67. **Zel'dovich, Ya. B. Converging cylindrical detonation wave.** ZhETF v. 36, no. 3 782-792

The properties of detonation waves close to the normal detonation wave are considered. A theory of the amplification of a converging cylindrical detonation wave is proposed which exactly describes the amplification at the start of the process. The theory gives satisfactory results even for small radii and considerable amplification of the wave.

68. Kucherov, R. Ya., and L. Rikenglaz. Slip-velocity and temperature jumps at the boundary of a gas mixture. | ZhETF v. 36, no. 6 1758-1761

The development of a method for finding the boundary conditions for the hydrodynamic transfer equations of a binary nonhomogeneous gas mixture on a non-absorbing solid surface is given. The conditions take into account slip-velocity and the gas interface.

1960

69. Petukhov, I. V. Numerical integration of laminar boundary layer equations. | DAN SSSR v. 132, no. 2 307-310

A method is presented for the exact integration of the equations of a boundary layer with arbitrary boundary conditions. The method can be generalized for the case of a laminar compressible boundary layer.

70. Petukhov, I. V. (Moscow). Integration of boundary layer equations using asymptotic solutions. | InSb v. 30 149-169

71. Avduyevskiy, V. S., and R. M. Kopyatkevich. Calculating the laminar boundary layer in a compressible gas in the presence of heat transfer and with arbitrary pressure distribution over the surface. | IzAN MeMa no. 1 3-11

An approximate method is given for calculating laminar boundary layer with heat transfer in hypersonic compressible gas flows with a high pressure gradient. Temperature variation on the wall and integral energy correlation are taken into account. Flows around plane, axisymmetrical blunt bodies and bodies with sharp leading edges are considered.

72. Bogdanova, V. V. A laminar three-dimensional boundary layer with longitudinal and transverse temperature gradients. IzAN MeMa no. 1 12-19

The problem is reduced to the solution of ordinary differential equations with variable coefficients. Longitudinal and transverse velocity profiles in the boundary layer, the lines of the flow, and the magnitude of friction on the surface are determined.

73. Ruminskiy, A. N. Boundary layer in radiating and absorbing media. IzAN MeMa no. 2 47-53

A system of approximate partial differential equations is derived without any unknown integral radiant characteristics. A solution is obtained for a laminar boundary layer on a plate in the form of a series in two variables whose terms are determined by means of quadratures. The results are true for gray and selective radiations.

74. Kuptsov, V. M. The method of characteristics for an axisymmetrical equilibrium flow of real gas. IzAN MeMa no. 2 138-144

An equilibrium flow of gas is studied at very high temperatures and high pressures. It is assumed that the flow is in equilibrium, without heat transfer and friction, and that the flow is uniform in the initial cross section.

75. Larish, E. Aerodynamic interaction in free molecule flow.

IzAN MeMa no. 3 117-120

Free molecule flow around several bodies of any shape (not only convex) is considered under the assumption that the dimensions of the entire system are smaller than the free molecular path. It is shown that the problem may be reduced to solving one linear integral equation. Since the form of this equation coincides with that of the equation of illumination theory, a method exists for simulating its solution which amounts to making photometric measurements.

76. Bunimovich, A. I. (Moscow). The effect of slip on the separation of a boundary layer.

IzAN MeMa no. 5 14-20

The effect of rarefaction on velocity profiles above the detachment point in flows around curved surfaces is discussed. Critical pressure gradient is considered.

77. Mezhirov, I. I. Turbulent boundary layer of a real compressible gas.

PMMe v. 24, no. 1 93-99

Equations for perfect gases are derived from equations of motion, continuity, and energy. The equations are generalized and applied to real gases (for example, dissociated air), with the enthalpies substituted for the temperatures.

78. Chernyy, G. G. (Moscow). The application of integral relationships in problems of strong shock waves.

PMMe
v. 24, no. 1
121-125

An expression is derived for determining the parameters of propagation of explosion shock waves by using an integral relation on the total energy of the shock and the piston theory.

79. Shidlovskiy, V. P. (Moscow). The laminar boundary layer on an infinite disk rotating in a gas.

PMMe
v. 24, no. 1
161-164

The laminar boundary layer on an infinite disk rotating at a constant angular velocity in a viscous gas is calculated.

80. Pavlov, K. B. (Bauman Higher Technical Institute). Theory of Prandtl-Meyer motion.

PMMe
v. 24, no. 1
165-166

The development of the theory for two-dimensional motion of the Prandtl-Meyer type is given. The particular case of flow in the presence of a shock wave ahead of the body, whose intensity decreases with increasing distance from the body, is covered.

81. Dem'yanov, Yu. A., and V. N. Shmanenkov. (Moscow). On investigating inverse flows in the region of a turbulent-boundary-layer separation.

PMMe
v. 24, no. 2
237-239

The free-turbulence pattern is used for analysis of flows in the region of

a turbulent-boundary-layer separation. Inverse flows in the stagnation region are taken into account. Plane and axisymmetrical problems (supersonic flow past a step and a blunt body with a needle nose, respectively) are discussed.

82. Sychev, V. V. On the theory of hypersonic gas flows with shock waves described by power functions. — PMMe v. 24, no. 3 518-523

Plane and axisymmetrical hypersonic gas flows with strong shocks whose shape is given by power functions are discussed. It is shown that a correction is necessary if utilizing the exact solutions for solving the corresponding self-similar gas-flow problems.

83. Lunev, V. V. Self-similar case of hypersonic flow of a viscous, heat-conducting gas past an axisymmetrical body. — PMMe v. 24, no. 3 548-550

An example of the flow past a slender, axisymmetrical body at $M \gg 1$ is discussed for the case in which the boundary layer has a substantial effect on the outer flow. It is shown that the solution of this interaction problem is self-similar.

84. Polyanskiy, O. Yu. Decay of shock waves in a moving medium having variable density and temperature. — PMMe v. 24, no. 5 912-915

The propagation and decay of shock waves are studied under the assumption that they are weak and that their

length is much smaller than the characteristic dimensions in the problem. Asymptotic formulas are derived for the excess pressure in wave fronts having a pressure profile.

65. Mikhaylova, M. P. (Moscow). Motion of a spherical piston at constant velocity through an inhomogeneous medium. | PMMe v. 24, no. 5 919-922

The motion of gas behind a spherical piston moving at constant velocity through an inhomogeneous medium is studied. The shock wave formed ahead of the piston is considered.

66. Chushkhin, P. I. (Computing Center, Academy of Sciences USSR, Moscow) Blunted bodies of simple shape in a supersonic gas flow. | PMMe v. 24, no. 5 927-930

A method of characteristics adapted to computer calculation of a supersonic gas flow around blunt bodies of simple shapes is presented. The results of calculation made by this method are given for several blunt cones and wedges.

67. Sandulescu, S. (Institute of Applied Mechanics, Rumanian Academy of Sciences, Bucharest). A method is presented for the characteristics of a three-dimensional boundary layer. | StuCeMeAp v. 11, no. 1 61-77

68. Frankl', F. I., and Voyshel', V. V. Turbulent friction in the boundary layer of a flat plate in a two-dimensional compressible flow at high speed. | 1937 TsAeGiI Report no. 321

TSAGI Report No. 321 (Transl. as NACA TM No. 1053 (1943)

89. Galanova, Z. S. The laminar boundary layer on a plate in the presence of dissociation. — VeLUMMeAs no. 1 95-99

Second-approximation solutions are presented of laminar-boundary-layer equations derived by M. Ye. Shvets (PMM, v. 13, no. 3, 1949) for a thermally insulated plate and for a plate with a given wall temperature. Results of numerical calculations for a thermally insulated plate at Mach numbers 10, 20, and 30 are given.

90. Dorodnitsyn, A. A. A method for solving laminar boundary-layer equations. — ZhPMeTF no. 3 111-118

A method suitable for computers is described which gives exact values of laminar boundary-layer parameters.

91. Koldobskaya, T. G. The problem of unsteady, nearly self-similar motion. — VeLUMMeAs no. 1 111-122

A method of linearization nearly identical with a self-similar solution is used. The method can be applied to plane shock waves in flow past wedges and cones.

92. Kutateladze, S. S., and A. I. Leont'yev. Turbulent friction on a flat plate in supersonic flow. — ZhPMeTF no. 4 43-48

It is shown that limiting solutions for turbulent boundary layers of compressible gases may be obtained by Prandtl's semi-empirical theory of turbulence.

93. Kosterin, S. I., and Yu. A. Koshmarov. (Institute of Mechanics, AS USSR, Moscow). Turbulent boundary layer on a flat plate in a uniform stream of a compressible fluid.

ZhTF
v. 29, no. 7
906-915

Translation: in Sov. Phys. Tech. Phys., Jan. 1960, 819-828.

An analysis is given of the effect of gas density variation on the distribution of velocities, temperatures, and densities in the boundary layer, and consequently, on friction and heat exchange for a plate in a gas stream.

94. Lun'kin, Yu. P. (Leningrad Physicotechnical Institute, Academy of Sciences USSR). Variation of gas parameters caused by nonequilibrium dissociation behind a shock wave.

ZhTF
v. 30, no. 6
622-626

An approximate method is presented for the solution of a system of equations which describes the nonequilibrium dissociation of monatomic and diatomic gases behind a shock wave. In deriving an expression for the temperature distribution, it is assumed that the heat capacities of the gases are constant.

95. Alekseyev, V. M. On the theory of perturbed motion. 1961 AsZh v. 38, no. 4 726-737

A system of differential equations describing the relative motion of two bodies acted upon by perturbations of any nature combined with Newtonian gravitation is replaced by an equivalent system of integral equations on the basis of which various estimates are made concerning the perturbed Keplerian motion, the hyperbolic approach of two bodies, and convergence of the method of successive approximations.

96. Charnyy, I. A., D. S. Vil'ker (deceased), B. I. Mitel'man, and G. D. Rozenberg. On two-phase supersonic flows. DAN SSSR v. 137, no. 1 48

The supposition that a liquid introduced in a supersonic gas flow (freezing temperature of liquid is considerably higher than that of the gas) freezes, thus forming a two-phase flow, was verified by an experiment (water and gas at M = 1.2 and 3). This phenomenon can be utilized in cooling of bodies in high-speed gas flows. A quantitative theory will be given in future work.

97. Kochina, N. N., and N. N. Mel'nikova. The theory of point explosions. DAN SSSR v. 138, no. 2 326-329

The problem of a point explosion in a compressible medium, as studied in the Steklov Institute of Mathematics, Academy of Sciences USSR, is presented theoretically in this article, which was recommended for publication by L. I. Sedov. References are given to studies devoted to various aspects of the point-explosion problem.

98. Pressman, A. Ya. On the flow of a rarefied gas from a point source into a vacuum. DAN SSSR v. 138, no. 6 1305-1308

A practically collision-free flow of particles of a sufficiently rarefied gas from a point source into a vacuum is considered from the standpoint of solving the Einstein-Fokker equations with a time-dependent "diffusion coefficient" and with boundary conditions.

99. Bazhenova, T. V. The gas-flow velocity behind the shock wave in a shock tube. EnI AN SSSR FGaTp 31-35

The evolution of heat in a gas flow in a shock tube is analyzed in order to establish the degree of uniformity in the interval between the shock wave and the interface and to verify the law of velocity changes in the shock wave region. Tests were made at M = 2 to 6.

100. Morozov, M. G., V. M. Yeroshenko, and Yu. P. Petrov. Flow in stagnation zones on surfaces in supersonic flow. EnI AN SSSR FGaTp 60-65

Experiments were carried out in an aerodynamic tunnel, with an air velocity of M = 1.69, to determine the direction and magnitude of flow velocity in stagnation zones and to study the general pattern of the flow and the distribution of static pressures on the periphery of stagnation pockets.

101. **Naboko, I. M.** Deflagration in the stagnation region over an obstacle in supersonic flow. EnI AN SSSR FGaTp 42-45

The shape of the shock wave and the direction of the flow behind it are discussed on the assumption that the detonation front is an infinitely thin surface and that an instantaneous reaction takes place in the front with some heat generation. Tests were made in a shock tube with a mixture of hydrogen and oxygen at a flow velocity of $M \leq 1.25$, which corresponds to a wave velocity of $M \leq 2.65$.

102. **Murzinov, I. N.** The influence of the boundary layer on flow past slender, blunted cones at high supersonic velocities. IzAN MeMa no. 1 152-153

The influence of a laminar boundary layer on the distribution of pressures along the generatrices of a cone is evaluated approximately by using the small disturbance method.

103. Larish, E. Equations of free molecular flow. IzAN MeMa no. 2 70-77

Equations describing steady and unsteady free-molecule flows past bodies are derived with rebound of gas particles taken into account. Flows with a slight variation of parameters about their mean values are considered.

104. **Stulov, V. P.** (Moscow). Boundary layer on a plate with nonequilibrium dissociation taken into account. IzAN MeMa no. 3 5-12

Viscous compressible gas flow past a plate under conditions making possible the dissociation and recombination of a diatomic gas is discussed.

105. **Tagirov, R. K.** Determining the base pressure and temperature in sudden expansions of sonic or supersonic flows. IzAN MeMa no. 5 30-37

A method for determining the base pressure and temperature in sudden expansions of plane or axisymmetric flows is discussed. The method is based on H. Korst's well known method, but it also takes account of nonisothermicity of mixing and propagation in the case of sudden expansion of an axisymmetric flow toward its axis of symmetry.

106. **Kolodochkin, V. P.** Calculation of a supersonic flow about cones at angles of attack. IzAN MeMa no. 5 38-43

The calculation consists of numerical integration of gasdynamics equations in three meridional planes. The results are compared with other calculation methods and with experimental data.

107. **Murzinov, I. N.** Flow of gas near the stagnation point of a blunted body at a finite excitation velocity of vibrational degrees of freedom. IzAN MeMa no. 6 33-36

An approximate solution is sought by determining the gas parameters between a shock wave and a body at $M \approx 7$. The influence of relaxation on the shock wave during motion of a sphere in air considered as a mixture of highly rarefied oxygen and nitrogen is calculated.

108. Kosterin, S. I., Yu. A. Koshmarov, and Yu. V. Osipov. Shock-wave position in a supersonic nozzle. — InFZh no. 4 3-9

An experimental study was made on the effect of the divergence angle in the supersonic section of a nozzle on the position of a shock wave at a given pressure ratio, with account taken of the effect of heat transfer. The study was conducted within the ranges of R_e and M numbers representing the actual operating conditions of the nozzle with the divergence angle varying from 0° to 50°.

109. Golubev, V. A. A study of a high-temperature gas stream. — InFZh v. 4, no. 6 42-50

A theoretical study is presented on a high-temperature plane-parallel gas stream. A purely turbulent stream is assumed, that is, the molecular viscosity, heat conductivity, and radiation energy are neglected. Discrete solutions for the differential equations of motion of the boundary layer are used, taking into account gas dissociation and ionization. The formulas derived permit rapid calculation of the gas-stream parameters at all points for any degree of initial preheating.

110. Keldysh, V. V. Exact solutions [in geometry] of lift-producing systems with one and two attached plane shock waves. InZh v. 1, no. 3 22-39

The shapes of lift-producing bodies in hypersonic air flows are discussed. The geometry of these bodies is taken from flow patterns behind one attached plane shock wave or two such intersecting shock waves. The geometric and aerodynamic characteristics of these bodies are determined for certain flight conditions.

111. Proshnikov, R. S. On almost free-molecule flow of rarefied gas around bodies. InZh v. 1, no. 3 60-64

The correction to values of aerodynamic characteristics obtained by free-molecule theory to obtain corresponding values for higher Knudsen numbers is discussed, and the significance of secondary collisions is pointed out. The applicability range of this correction is pointed out.

112. Bakulev, V. I. Calculation of the turbulent mixing flow of a real gas. InZh v. 1, no. 3 65-74

The solutions of the problem of the boundary layer in the initial portion of a plane-parallel, low-temperature real-gas (with solid and liquid phases eliminated) jet is presented. The investigation is based on Prandtl's theory of free turbulence, with the additional assumption that the mixing lengths are larger for scalar quantities (heat, density) than for vector quantities (momentum), that is, taking into account the rotation of the particles.

113. Kerimgaziyev, E. Investigation of transonic flow past a body for the purpose of designing an airfoil. — InZh v. 1, no. 3 75-85

High-speed subsonic flow around a body of arbitrary shape, with a shock wave at the rear of the supersonic region is investigated. Transonic symmetrical flow past a symmetrical airfoil is constructed by an approximate method. By applying equations for velocity, potential, and stream function, a flow pattern is obtained which suggests the shape of a double-wedge airfoil.

114. Galkin, V. S. Applicability limits of relaxation models of Boltzmann's kinetic equation [in the aerodynamics of rarefied gases]. — InZh v. 1, no. 3 153-156

Boltzmann's equation is simplified by using assumptions concerning the collision of molecules. The solution of the system of " model" equations is compared with the solution of an exact system of kinetic momentum equations of an ideal monatomic gas, and the limits of applicability for the models are established.

115. Nikol'skiy, A. A. One class of exact solutions of three-dimensional gas-dynamics equations. — InZh v. 1, no. 4 11-17

The calculation is simplified by introducing cylindrical coordinates in the area of the velocity hodograph, and partial solutions are made possible by the method of separating the Fourier variables. These partial solutions lead to an exact solution of three-dimensional gas dynamics equations. The method is useful in the analysis of supersonic flow over fuselage-type bodies.

116. Fadeyev, S. I. Gas flow in a discharge tube. | InZh v. 1, no. 4 137-140

One-dimensional unsteady flow of a perfect gas in a discharge tube is analyzed for the case where the energy release in the discharge gap is a function of time and is a determining factor of the process. A relationship between the energy release law and the law of the motion of a shock wave is derived.

117. Kostyochev, G. I. (Kazan' Aviation Institute). On optimal body shape in unsteady flows. | KAvI, Tr no. 4 34-38

The determination of optimal body shape and the effect of unsteadiness on optimal shape are discussed.

118. Stanyukovich, K. P., and V. P. Shalimov. On the motion of meteor bodies in terrestrial atmosphere. | Meteoritika no. 20 54-71

Two stages of meteor motion in the earth's atmosphere are discussed: 1) in the upper layers of the atmosphere where the free path of the air molecules is larger than the diameter of the meteor body and 2) in the lower layers where a strong shock wave is formed in front of the body.

119. Chernyy, G. G. (Moscow). A method of integral relations for analyzing gas flows with strong shock waves. | PMMe v. 25, no. 1 101-107

A general approach to utilization of integral relations in the solution of problems related to flows with strong shock waves is presented. Some particular sample problems concerning the detonation waves, and waves in shock tubes are discussed.

120. Arkhimov, V. N. Plane-parallel flow of compressible fluid in the wake of a body. | PMMe v. 25, no. 1 138-139

Equations of motion, continuity, and energy are formulated for the following conditions: at a given distance from the body, the pressure is approximately constant in the cross section of the wake, the transverse velocity is small as compared with the longitudinal velocity, the rate of change in longitudinal velocity, along the axis of the wake is small as compared with the rate of its transverse change, and the rate of pressure change along the wake is negligible.

121. Fal'kovich, S. V. (Saratov). Near-sonic plane laminar gas flow with singular points on the sonic line. | PMMe v. 25, no. 2 218-228

Near-sonic plane laminar flows with singular points on the sonic line were studied. Solutions with a singular point on the sonic line of Tricomi's equation and solutions of Chaplygin's equation are used to obtain solutions in the form of an infinite series, the first term of which is the corresponding "self-simulating" solution of Tricomi's equation. The cases of wedge-shaped profiles and flat plates are considered as illustrative examples.

122. Medukhovskiy, I. B. (Moscow). The flow at an angle of attack past a finned body of revolution. | PMMe v. 25, no. 3 561-566

The regularity patterns of a flow past a body of revolution are discussed using general assumptions on the relation between

aerodynamic flow parameters and orientation of the velocity vector of the oncoming flow relative to the meridians. Dependence of aerodynamic forces on the angle of attack of a longitudinally finned body of revolution is discussed as well as the number of fins, assuming that there is no aerodynamic interference between them.

123. Sychev, V. V. (Moscow). Hypersonic gas flow of a viscous, heat conducting gas. — PMMe v. 25, no. 4 600-610

Motion of a body in hypersonic flow of a viscous heat conducting gas is studied and equations characterizing the gas flow around the body are derived on the basis of the Navier-Stokes equation for an infinite Mach number. General common properties of steady hypersonic flow around bodies with formation of a strong shock wave, and self-similar unsteady flows with $t^{*} = 0$ in the undisturbed region x are discussed.

124. Galkin, V. S., and A. A. Gladkov (Moscow). Lift at hypersonic speeds. — PMMe v. 25, no. 6 1138-1139

Presents a study demonstrating that the lift for a large class of bodies (wedge, cone, et cetera, but not a cylinder or plate) in a free-molecule hypersonic flow at any value of Knudsen number and in a continuum hypersonic flow is negative for any angle of attack in the range from zero to 90°.

125. Dorodnitsyn, A. A. Solution of boundary layer equations. — IPMMe, ANSSSR Sib. O. Sb. 77-83

A short presentation is made of one method for the exact solution (with any degree

of accuracy) of equations of a laminar boundary layer of a noncompressible liquid. Two examples are presented which show the rate of convergence of the method. It is noted that although setting up the system of differential equation is a tedious process, the solution of the system on high-speed computers is simple.

126. Ginzburg, I. P. (Leningrad State University). Turbulent boundary layer on a plate in a compressible flow. VeLUMMeAs no. 1 75

The skin friction and heat transfer on a flat plate in a turbulent hypersonic flow at arbitrary Prandtl numbers are determined with dissociation and diffusion taken into account.

127. Kulonen, L. A. Calculating the parameters of a laminar boundary layer on a flat plate in dissociating gas. VeLUMMeAs no. 1 128-132

Equations for a laminar boundary layer on a flat plate are solved with the chemical nonequilibrium dissociation of a diatomic gas under conditions of incomplete thermodynamic equilibrium taken into account, under the assumption that the specific enthalpies of atomic and molecular components are arbitrary functions of gas temperatures.

128. Belova, A. V., and S. V. Vallander. Integral kinetic equations in the theory of monatomic gases in an external field of body forces. VeLUMMeAs no. 2 75-80

The system of equations derived is intended to describe a gas flow subjected to a constant external field of body forces. It is shown that the equations can be used for a variable external field with negligible variations. In deriving the equations, the fact was taken into account that the trajectories of atoms in the external field of body forces are curvilinear.

129. Vallander, S. V., and A. V. Belova. Integral kinetic equations for gas mixtures with internal degrees of freedom. VeLUMMeAs no. 2 81-86

A system of integral kinetic equations is presented for a mixture of polyatomic gases flowing in a constant external field of body forces in the presence of chemical reactions. The system of equations can be solved by the method of successive approximations. It is assumed that for gas motion only molecular collisions in pairs are essential and that the gas particles formed by the chemical reactions are electrically neutral.

130. Kulonen, L. A. A method for analyzing a laminar boundary layer on a porous surface. VeLUMMeAs no. 2 123-135

The laminar boundary-layer problem of the motion of a binary mixture of gases with different physical properties is considered for the general case of a variable free-stream velocity, a variable surface temperature, and an arbitrary relationship between the mass-transfer coefficients, temperature, and concentration. The method can also be used for solving the problem of gas-mixture motion on a boundary layer with injection through the porous surface.

131. Koldobskaya, T. G., and I. A. Sychev. Irregular reflection of a shock wave from a curvilinear wall. VoLUMMeAs no. 3 111-130

The problem is solved by Paper's method with some additional assumptions. A series of experimental investigations was made to compare data for reflection from curvilinear profiles and wedges.

132. Ryzhov, O. S. Decay of shock waves in inhomogeneous media. ZhPMeTF no. 2 15-25

Physical phenomena associated with the propagation of small-amplitude waves in a nonuniform medium are explained. The interaction of two shock waves is analyzed for the case in which one overtakes the other.

133. Lunev, V. V., and I. N. Murzinov. Effect of radiation on the flow in the stagnation point region of a blunt body. ZhPMeTF no. 2 26-30

The effect of thermal radiation of a gas on its flow parameters near the stagnation point of a blunt body is discussed, disregarding the radiation pressure, the interaction between radiation and oncoming flow in the shock layer, and the effect of the thin boundary layer.

134. Ryzhov, O. S. The decay of shock waves in steady flows. ZhPMeTF no. 6 36-43

The basic characteristics of the development of shock waves of small amplitude in nonhomogeneous steady supersonic flows are studied for the case where the width

of the disturbed-flow region is assumed to be small compared with the radius of curvature of the shock waves and the distance at which the parameters of the initial medium change appreciably.

135. Sayasov, Yu. S. Structure of an oblique shock wave in a chemically reactive gas. ZhPMeTF no. 6 172-174

The system of equations describing the flow or a chemically reactive inviscid gas behind an oblique shock is used in analysis of flow parameters behind the shock wave. Assumptions are made that the front of the shock wave is plane and that the flow lines behind the shock wave are rectilinear.

136. Grebenshchikov, S. Ye., M. D. Rayzer, A. A. Rukhadze, and A. G. Frank. ZhTF v. 31, no. 5 529-538

In an experimental study of the interaction of converging ring-type shock waves with a " magnetic wall," shock waves were produced in a vacuum chamber at a frequency of 360 kc by discharging two parallel-connected 0.2-μf capacitors through a copper ring surrounding the chamber. Comparison of the experimental results with those obtained theoretically for plane shock waves interacting with a magnetic wall showed close agreement.

137. Lun'kin, Yu. P., and F. D. Popov. Nonequilibrium dissociation of a gas mixture behind a shock wave. ZhTF v. 31, no. 6 726-730

Nonequilibrium dissociation of a mixture

of two diatomic, or of one monatomic gas and one diatomic gas behind a normal shock wave is investigated. An approximate method of solving the equations (of conservation of state and of relaxation) which describe such dissociation is presented.

138. Gvozdeva, L. G. (Laboratory of Combustion Physics, Krzhizhanovskiy Institute of Power Engineering, Moscow). Refraction of detonation waves by incidence on the boundaries between two gaseous mixtures. — ZhTF v. 31, no. 6 731-739

A motion picture investigation of rarefaction of a shock wave moving in a reacting medium as it passes through a boundary between this medium and an explosive or inert medium is presented.

139. Lun'kin, Yu. P. (Ioffe Physicotechnical Institute, Leningrad). Measurement of entropy in the relaxation of a gas mixture behind a shock wave. — ZhTF v. 31, no. 9 1112-1118

The relaxation of a mixture of a diatomic gas and a monatomic gas behind a shock wave is analyzed. The excitation of degrees of freedom and entropy changes behind weak and strong shock waves are discussed.

140. Koryavov, P. P. Numerical calculation of laminar flows. — ZhVychMMF v. 1, no. 5 856-868

The problem of jet mixing of two steady laminar semi-infinite flows of compressible viscous gases of different velocities and temperatures is considered. A method is presented for numerical calculation of

velocity and temperature profiles in the mixing zone on the basis of the general boundary layer theory, under the assumption that parameters of gas density—viscosity, heat transfer, and specific heat at constant pressure are known functions of temperature.

141. Shchennikov, V. V. (Moscow). An analysis of a laminar boundary layer over a sub-liming surface. — ZhVychMMF v. 1, no. 5 869-883

Equations are derived and boundary conditions are established for analysis of the laminar boundary layer over a subliming, axisymmetric, blunted body in a high supersonic flow, taking the chemical reactions into account.

142. Godunov, S. K., A. V. Zabrodin, and G. P. Prokapov. A difference scheme for two-dimensional gas dynamics problems. — ZhVychMMF v. 1, no. 6 1020-1050

A method was developed for the numerical solution of two-dimensional gas dynamics problems. The difference computational scheme for gas dynamics equations and the formulas for approximate calculation of the decomposition of discontinuity were worked out and are presented in detail. The stability of the difference scheme was studied only for the case of a linearized system of gas dynamics equations with constant coefficients; necessary and sufficient stability conditions of the scheme for this sytem were derived. The difference method is also applied to the case of a homogeneous supersonic flow of an ideal gas around a sphere.

143. Babenko, K. I., and G. P. Voskresenskiy. A numerical method for calculating the flow of gas around bodies. — ZhVychMMF v. 1, no. 6 1051-1060

A method for numerical calculation of the three-dimensional supersonic flow of an ideal gas around pointed bodies has been developed. Programs are worked out for electronic digital computers, and calculations are made of the flow around a circular cone and a body of revolution for various values of Mach number and of angle of attack.

144. Dorodnitsyn, A. A. Numerical methods for solution of laminar boundary-layer equations. — 1962 ~~Arch~~ MeSt v. 14, no. 3/4 343-357

A general method of integral relations used at the Computing Center of the Academy of Sciences USSR for the solution of complicated boundary-layer problems by means of high-speed computers is described. General expressions are derived for integral relations for a boundary layer in a "classical" compressible fluid (that is, without chemical reactions and radiation) which can easily be adapted to incompressible fluids.

145. Lubonski, J. Hypersonic plane couette flow in rarefied gas. — Arch MeSt v. 14, no. 3/4 553-564

Hypersonic plane Couette flow in a rarefied gas is considered in terms of a certain approximation method which is of more general use than conventional ones and can be applied to other hypersonic flows. A flow between two walls which reflect molecules diffusely is considered because of its simplicity. Fields of macroscopic values, such as density, mean velocity, and temperature are investigated. The molecules are grouped into three classes according to their motion origin. The gas is regarded as a mixture of the three classes and the molecules are considered as rigid spheres.

146. Goz'kov, L. P., and L. P. Pitayevskiy. The origin of a shock wave caused by reflection of a weak discontinuity from the sonic line. — DAN SSSR v. 144, no. 2 293-296

The reflection of the weak discontinuity (the discontinuity of the first derivatives of velocity) from the sonic line was studied with the aid of the Euler-Tricomi equation describing the sonic flow of gas. Formulas describing the change of parameters on a shock wave are derived.

147. Bazhenova, T. V., and O. A. Predvoditeleva. A comparison of air parameters behind shock waves. — EnI AN SSSR FGaTp 15-24

Thermodynamic and gas dynamic parameters behind normal, incident, and reflected shock waves are compared under certain assumptions on equilibrium dissociation of air; the excitation of degrees of freedom of particle is considered.

148. Anfimov, N. A. The laminar boundary layer in a multicomponent mixture of gases. — IzAN MeMa no. 1 25-31

The equations of a laminar multicomponent boundary layer are solved in the neighborhood of the stagnation point of a blunt body in a flow of dissociated air. It is assumed that the chemical reactions inside the boundary layer are frozen and that the state of the gas at the wall and in the outer boundary of the layer is in equilibrium.

149. Avduyevskiy, V. S. (Moscow). Analysis of a three-dimensional laminar boundary layer along geodesics in the flow. — IzAN MeMa no. 1 32-41

Differential equations are derived for flows in the regions of the geodesics on a cone under an angle of attack, slip flow past an infinite cylinder, and at the forward stagnation point. Formulas are given for calculating the parameters of heat transfer, friction, and boundary layer.

150. Shidlovskiy, V. P. Flow of slightly rarefied gas about a sphere. — IzAN MeMa no. 2 17-24

Slip flow about the forward part of a sphere is considered. This flow corresponds to Knudsen numbers K from 0.1 to 0.01. It is assumed that the Mach number is of the order of 1/K.

151. Mel'nikov, D. A. Shock wave reflection in a supersonic gas flow. — IzAN MeMa no. 3 24-30

The problem is studied of a gas flow through the region of an incident shock wave reflected from the axis of symmetry, where a normal shock wave is formed. A method is developed for determining a subsonic flow beyond the normal shock wave. Shadow photographs are given of flows from four axisymmetrical nozzles of different shapes, with uniform and nonuniform velocity fields and Mach numbers from 2.8 to 3.2 and 2.67 to 3.37.

152. Anfimov, N. A. The laminar boundary layer on a chemically active surface. — IzAN MeMa no. 3 46-52

The burning of a blunted semi-infinite

body (consisting of various carbon, oxygen, and hydrogen compounds) in a flow of high-temperature air is discussed. The boundary layer in an eight-component gas mixture in the presence of chemical reactions and mass exchanges on the body surface is examined. A method is given for determining the rate of burning and the surface temperature is given.

153. Shkadov, V. Ya. A solution of the boundary layer problem. IzAN MeMa no. 3 173-175

The flow of a viscous incompressible fluid in a boundary layer is studied and equations with solutions which satisfy particular boundary conditions are analyzed. Analytical series are employed to derive two satisfactory solutions, for boundary layers starting at the boundary edge and at the critical point and for bodies with sharp and blunt edges.

154. Vulis, L. A. An interpolation formula for a transient region of flow. IzAN MeMa no. 3 180-182

An interpolation formula is presented, based on phenomenological treatment of the process of transition from a steady laminar regime to a turbulent one, which is applicable to integral (drag, heat transfer, et cetera) and local (effective viscosity and temperature conductivity in a turbulent boundary layer) governing laws.

155. Avduyevskiy, V. S. A method for analyzing a three-dimensional turbulent boundary layer in compressible flow. IzAN MeMa no. 4 3-12

A method is developed for calculating a turbulent boundary layer in a compressible

two- or three-dimensional hypersonic flow on an arbitrary curvilinear surface. The formulas for a flat plate are applied at every point of the body, and in place of the true length along the surface of the body, a certain effective length which satisfies the basic integral correlations is considered. The expressions for the parameters of a turbulent boundary layer, are obtained by analyzing experimental data on turbulent boundary layers. Calculation of the friction drag at Mach 6 on an axisymmetrical ideal nozzle is presented, as are sample calculations of the heat exchange for a Mach 10 three-dimensional flow around a cylinder of infinite length, and around sharp- and blunt-nosed cones. The effect of the shock-wave curvature is taken into account and discussed.

156. Dorfman, L. A. The boundary layer on bodies rotating at high velocities. — IzAN MeMa no. 4 18-22

An approximate method is presented for calculating the boundary layer on axisymmetrical bodies (turbine wheels, propellers, rotors, and projectiles) rotating at high velocities in axial flows. The inflow ("ventilating") effect of rotation on the flow in the boundary layer is taken into account. A comparison of the results with those obtained by the method set forth by E. Truckenbrodt in 1954 indicates that the present method gives values closer to experimental data.

157. Cherkez, A. Ya. Averaging of supersonic gas-flow parameters. — IzAN MeMa no. 4 23-26

The possibility of using the relations and methods of one-dimensional gas dynamics in the study of highly irregular supersonic flows is considered. It is demonstrated that for irregular supersonic flows in which the stagnation temperature is constant, it is possible to find average parameters which will satisfy the flow conditions.

158. Avduyevskiy, V. S., and Ye. I. Obroskova. Laminar boundary layer on a porous plate in the presence of chemical reactions on its surface. — IzAN MeMa no. 5 3-12

A laminar boundary layer with chemical reactions on a porous plate through which a gas is injected is discussed. Approximate formulas are derived for determining the boundary-layer parameters, with carbon and hydrogen burning on the plate surface and binary diffusion in the boundary layer.

159. Cherkez, A. Ya. One-dimensional theory of supersonic gas jets. — IzAN MeMa no. 5 13-15

The one-dimensional theory is shown to give quantitative results conforming with experimental data, to determine qualitative flow laws, and to disclose the physical meaning of some characteristics of the initial portion of the jet.

160. Kireyev, V. T. Shock wave propagation in a shock tube. — IzAN MeMa no. 6 144-146

A flow pattern is presented for determining the variations in shock wave velocity and flow parameters of the driving and driven gases during diaphragm opening. Results of numerical calculation of the shock wave velocity and cross-section area variation of the opening are presented in graphs.

161. Lunev, V. V. (Moscow). A shock layer method in problems of hypersonic flow over thin blunted bodies. — IzAN MeMa no. 6 146-147

The method proposed by H. Cheng, T. Hall, T. Collian, and A. Hertzberg for approximate calculations of a flow over thin blunt bodies is analyzed. It is shown that the solution obtained for any isentropic exponent not equal to unity contradicts the results obtained by G. G. Chernyy, who used another method, which gives, in general, more accurate results.

162. Kutateladze, S. S., and A. I. Leont'yev. Calculating turbulent boundary layer parameters under essentially positive pressure gradients. — InFZh v. 5, no. 1 33-41

A new successive-approximation method for calculating the parameters of a turbulent boundary layer was developed. The analysis is based on the limiting laws of friction and heat exchange in the diffusion region of gas flow. Equations for determining the velocity profile within the turbulent layer, the drag distribution, and the limit-velocity profile at the point of separation are also derived and show good agreement with experimental data.

163. Romishevskiy, Ye. A. (Moscow). Boundary layer and steady gas discharge diffusion-pattern radiation. — InFZh v. 2, no. 1 170-174

The process of the interaction of a viscous radiating gas-flow at reentry velocities with the surface of a body in a thin layer which has a boundary-layer pattern is discussed, as well as phenomena in a steady gas discharge under high pressure which are of the same character. It is assumed that the radiation range is small and has a diffusion pattern.

164. Slezenko, Z. F. The velocity profile of the boundary layer on a nonuniformly heated plate. InFZh v. 5, no. 10 47-52

A method was devised for direct measurement, with an accuracy of 0.01 to 0.005 cm/sec, of local values of the small-velocity profiles in the boundary layer on a nonuniformly heated plate. Based on the photoelectric principle, the method is applicable to weakly rarefied and nonrarefied gases. A circuit diagram of the device used in the measurements is given, along with the method of calculating velocities from a nomogram.

165. Kostychev, G. I., and V. I. Polkovnikov. Variational problems of gas dynamics. IzVUZ AvT no. 1 11-18

The effect of flight conditions on the optimum form of an aircraft and its vertical motion are studied.

166. Dulov, V. G. An approximate method for calculating slightly divergent supersonic axial flows. IzVUZ AvT no. 2 8-14

For the calculation of slightly divergent supersonic isentropic gas flow, the Leningrad Institute of Mechanics has developed an approximate method which combines and to some extent is based on two classical methods, that of characteristics and that of the linearization of equations and boundary conditions.

167. Dulov, V. G. Shock-wave propagation in a variable-cross-section channel. IzVUZ AvT no. 3 17-24

The propagation of a shock wave formed in a gas duct of constant cross section and moving through a short divergent channel is analyzed and the dependence of shock wave parameters on the area of the cross section of the channel is established.

168. Tolstykh, A. I. A turbulent boundary layer with pressure gradients on a porous surface. InZh v. 2, no. 1 79-86

The problem is analyzed for incompressible gases, and the results are generalized for compressible gases. The equations may be used for calculating any general case of a turbulent boundary layer with diffusion and heat transfer.

169. Nikol'skiy, A. A., and B. A. Smirnov. Action of a shock wave on an obstacle. InZh v. 2, no. 1 181-188

Some specific obstacles, both two- and three-dimensional, are considered. The overall impulses and moments and also the distribution of pressure impulses on the surface of the body are determined. It is shown that when the velocity is sufficiently low and vorticity may be neglected, the problem can be reduced to the case of incompressible-fluid flow.

170. Stanyukovich, K. P. Variation of arbitrary constants in self-similar solutions. InZh v. 2, no. 2 355-358

An approximate method for calculating the variation of arbitrary constants in the propagation of moving shock waves is presented. The new solutions are based on the principle that any motion of gases in small volumes for short time intervals may be considered self-similar.

171. Neyland, V. Ya., and G. I. Taganov. The flow pattern in the separation region. InZh v. 2, no. 3 36-42

A general solution of the problem of the flow in the boundary-layer separation region with a return flow is presented.

The study is restricted to the plane flow of an incompressible fluid within the plane flow of an incompressible fluid within the stagnation zone, and to a supersonic flow past a body with a needle fixed at its front. The formation of separation zones, the zone angles, and the velocity profiles are discussed in both flows.

172. Petukhov, I. V., and A. L. Ankudinov. The effect of flow vorticity and body curvature on boundary layer. — InZh v. 2, no. 4 262-268

The effects of flow vorticity outside the boundary layer, as well as of the curvature of body contour, on the structure of the boundary layer are analyzed by using a strict formulation of boundary conditions for the secondary streams in the layer. The results of this analysis were used as a correction of the known solution of this problem (without outer-flow vorticity) by Blasius.

173. Shcherbina, Yu. A. The effect of initial turbulence on the boundaries of a mixed jet. — MoFTI no. 7 152-157

Results are presented of an experimental investigation of a two-dimensional mixed jet in its initial region, where the structure of the jet is disrupted due to high turbulence. Turbulence measurements were made by the optical-diffusion method at the same distance from the nozzle grid in all cases. Initial velocity was kept constant in all of the experiments. The schematic diagram of an experimental device is given, as well as graphs of velocity distribution and relative boundaries of the mixing region.

174. Ladyzhenskiy, M. D. An analysis of hypersonic flow equations and the solution of the Cauchy problem. PMMe v. 26, no. 2 289-299

General equations of hypersonic vortex flows are investigated. The approximate solution of the Cauchy problem is compred with exact analytical and numerical solutions. The results can be used for studying internal hypersonic flow.

175. Zhilin, Yu. L. Similitude parameters at high hypersonic velocities. PMMe v. 26, no. 2 387-388

Similarity conditions established by W. D. Hayes and R. F. Probstein for intermediate hypersonic velocities are extended to high hypersonic velocities. Analytical expressions are given.

176. Kogan, M. N. Hypersonic flows of a rarefied gas. PMMe v. 26, no. 3 520-529

The basic theoretical concepts and the criteria and conditions for the existence of near-free-molecular hypersonic flows are discussed. Flow past a plate perpendicular to the flow direction is considered for various Mach numbers and collision cross sections. It is assumed that reflection of molecules from the plate is diffusive with a Maxwellian velocity distribution.

177. Galkin, V. S. On the lift in a free molecule flow. PMMe v. 26, no. 3 567

It is shown that the lift of certain finite-length bodies in a free-molecule flow can be negative at any angle of attack between 0 and 90° and with forces acting on bases of such bodies taken into account.

178. Kulkovskiy, A. G. On shock-wave structure. PMMe v. 26, no. 4 631-641

Solutions of general gas-flow equations which can be used in gas-dynamics and magneto hydrodynamics and analyzed and the structure and behavior of shock waves are discussed.

179. Ladyzhenskiy, M. D. Flow of viscous gas into vacuum. PMMe v. 26, no. 4 642-649

Viscous, heat-conducting gas flows from two-and three-dimensional sources were studied by using Navier-Stokes equations with the assumptions that the coefficients of viscosity and heat condictivity are power functions of temperature and that the Prandtl number is constant. An asymptotic solution is sought for the case of the flow of gas into a vacuum when the pressure at infinity approaches zero.

180. Jakob, I. A., A. Zaharescu, and L. Dumitrescu. A method for measuring the velocity of shock-wave propagation. RevMeAp v. 7, no. 1 173-183

A method for measuring the velocity of shock-wave propagation is discussed. The measurements by a simple and compact unit with circuit components of original design are accurate to 0.2 to 0.5% for Mach numbers from 1 to 4. The arrangement of the system is described and shown in a diagram; a concise description of the characteristics of the component blocks is given.

181. Losev, S. A., and Osipov, A. I. An investigation of nonequilibrium phenomena in shock waves. UsFN v. 74 393-434

The following nonequilibrium phenomena were investigated in shock waves: 1) equalizing processes based on the kinetic theory of gases (qualitative study); 2) the state of the gas in a shock wave (experimental study). The operation of a shock tube was also studied.

182. Filippov, B. V. A variant of unsteady kinetic equations in rarefied-gas aerodynamics. — VeLUMMeAs no. 1 142-146

Unsteady gas flow is described by a system of kinetic integral equations derived for the case in which the initial value of the distribution function is given.

183. Tsibarov, V. A. Relationship between equations of the kinetic gas theory. — VeLUMMeAs no. 1 147-151

The connection between the solutions of integral-differential and integral-kinetic equations derived by Vallander, Fenner, and Sinter is established.

184. Vallander, S. V., E. A. Gurmuzova, and B. V. Filippov. Kinetic integral equations for an arbitrary conservative field of external forces. — VeLUMMeAs no. 3 87-89

A system of kinetic integral equations is presented which describes the motion of a gas consisting of particles with internal degrees of freedom moving in an arbitrary field of mass forces changing so slowly that they can be considered constant within the limits of a molecule.

185. Aleksenko, I. I., R. G. Barantsev, and I. N. Panteleyeva. The method of transversal approximation in hypersonic flow.

VeLUMMeAs no. 4 62-77

The method of transversal approximation is used for establishing the relation for the variation of flow parameters across the layer between the shock wave and the body along the normal to the shock wave. The basic features of the method are analyzed through quadratic approximation of the stream function; a detailed and complete study is carried out for the case of linear approximation.

186. Lugovtsov, B. A. (Novosibirsk). The propagation of a shock wave from a distant explosion in a water reservoir of constant depth.

ZhPMeTF no. 3 31-39

The site of the explosion is located at a distance (comparable to the depth of the reservoir) such that the disturbances caused by the passage of the shock wave are quite small, thus permitting one to consider the motion caused by this passage as short-wave propagation.

187. Mezhirov, I. I. One-dimensional gas flow in a channel of varying cross section in the presence of friction and heat exchange.

ZhPMeTF no. 3 92-95

The problem of calculating one-dimensional gas flow in a channel with varying cross section in the presence of friction forces and heat exchange between the gas and the external medium is considered. The effect of these factors on the total gas pressure is determined, and the problem of determining the channel-area variation necessary to obtain a designated Mach-number distribution for a given heat exchange law is solved.

188. Leonas, V. B. A study of interaction between free-molecule flow and a wall. ZhPMeTF no. 6 39-44

A method of experimental laboratory measurement of the coefficient of impulse transmission in the flow of a rarefied gas against a surface is discussed. An installation for producing a high-speed molecular beam from a supersonic jet of rarefied gas is described, and the results of a study on the angular distribution of recoil molecules are given. Measurements of the velocities of recoil particles are also presented.

189. Korobeynikov, V. P. An analogy between a cylindrical explosion and hypersonic gas flow past bodies. ZhPMeTF no. 6 45-49

An approximate analytical method for determining the law for the motion of an explosion wave and the pressure in the center of the blast is presented. The procedure used in this method is compared with that employed in the analysis of an inviscid hypersonic flow past blunted bodies. It is shown that with an increased Mach number, the shape of the shock wave in the flow approaches that of an explosion wave.

190. Lapin, Yu. V. (Leningrad Polytechnical Institute). A turbulent boundary layer in dissociating gas. ZhTF v.32, no. 4 473-479

The influence of equilibrium dissociation of an "ideal dissociating gas" on friction and heat transfer in a turbulent boundary layer of a plane plate is studied.

191. Kulonen, G. A. Application of the Kochin-Loytsyanskiy method to analysis of a laminar boundary layer with an interface. — ZhTF v. 32, no. 4 480-484

The flow parameters of a two-dimensional boundary layer at the stagnation point are discussed. It is assumed that a film is formed on the surface of a body from a substance which is in a different phase (gaseous or liquid) than that of the oncoming flow, so that an interface is formed; The densities of both phases are constant, and their physical properties independent of the temperature. The surface-tension forces are neglected.

192. Lozgachev, V. I. The theory of free molecule flow. II. Passage through chambers of arbitrary shape. — ZhTF v. 32 no. 9 1123-1133

The general problem of free-molecule flow through a chamber with arbitrary location of the inlet orifice and the outlet orifice is considered, that is, the probability of a molecule passing through the chamber is sought. It is assumed that the mean free path of a single molecule is greater than any dimension of the chamber, that there is no interaction between molecules, and that the chamber walls reflect all incident molecules according to a specific law.

193. Belotserkovskiy, O. M. (Computing Center, Academy of Sciences USSR). Supersonic flow of perfect and real gases around blunt-nosed bodies. — ZhVychM&F v. 2, no. 6 1062-1085

The method of integral correlation is applied to the problem of hypersonic flow around blunt bodies at Mach numbers $M_\infty = 4$ to $M_\infty \to \infty$.

194. Hess, H. (Physikalisch-Technisches Institut, Bereich Strahlungsquellen, der deutschen Akademie der Wissenschaften). Discontinuity conditions in the front of an ionizing shock wave.

1963 v. 5, no. 7 426-429

The gasdynamic parameters upstream from an ionizing shock wave propagating in helium at 25 mm Hg, at velocities of less than 20 M, were calculated by means of the Rankine-Hugoniot equations, equations of state, and the Saha equation for ionization. The density, pressure, temperature, gas velocity, and degree of ionization were plotted for ionizing and nonionizing waves as functions of M up to M = 18.

195. Mikhaylova, M. P. Motion of gas behind an asymmetrical piston.

DAN SSSR v. 148, no. 1 61-63

The motion of piston in a homogeneous gas is inv stigated under the assumption that the gas in front of the piston is at rest. The solution is sought for self-similar motion of the gas behind a piston moving at a constant speed.

196. Korobeynikov, V. P., and V. P. Karlikov. The parameters and shape of a shock wave front produced by an intense explosion.

DAN SSSR v. 148, no. 6 1271-1274

An approximate method is presented for calculating the parameters and shape of a shock wave produced by a point explosion in an inhomogeneous medium. Analytical relationships permitting determination of the shape are given, together with the law of its change with time. The method can be applied to the problem of explosions in a nonisothermic atmosphere.

197. Kuksenko, B. V. (Moscow State University). A method of rarefied-gas-flow analysis. | DAN SSSR v. 151, no. 5 1040-1045

A method is outlined for setting up systems of equations for many functions of a small number of independent varibles which are sufficient for obtaining an approximate solution of aerodynamic problems of rarefied gases.

198. Struminskiy, V. V. (Corr. member, AN SSSR). On the nonlinear theory of aerodynamic stability. | DAN SSSR v. 151, no. 5 1046-1049

The successive-approximation (small-parameter) method is applied to the study of the aerodynamic stability of disturbed viscous incompressible fluid flows between two parallel walls and in the boundary layer. The bounds of stability and the development of disturbances with time are discussed.

199. Petrosyan, L. G. On the solution of the boundary-layer equation. | IzAN ArmSSR FM v. 16, no. 5 91-98

A solution of the boundary-layer differential equation is presented in the case when the pressure gradient is zero and the equation of the potential-flow velocity are given. Expressions for the flow parameters and shear stresses on a plane surface are derived.

200. Ginevskiy, A. S., and Ye Ye. Solodkin. The effect of transverse surface curvature on characteristics of an axisymmetric, non-isothermal, compressible turbulent boundary layer. | IzAN MeMa no.1 99-113

A theoretical investigation of the above-mentioned problem in a high supersonic flow is presented. Flows past convex (cylindrical) and concave (channel) surfaces are discussed for various Reynolds and Mach numbers, and various values of a temperature parameter are discussed.

201. D'yakonov, Yu. N., and N. A. Zaytseva. Supersonic flow of an ideal gas about a blunted body. — IzAN MeMa no. 1 118-123

The axisymmetrical supersonic flow field around a blunt body is investigated. The results of calculations for flows at M = 3, 4, 6, 10 and past a sphere and past spherically blunted cones are presented.

202. Shkadov, V. Ya. The boundary layer with pressure gradient in compressible fluid flow. — IzAN MeMa no. 2 28-32

A boundary layer problem in a compressible fluid flow under the assumption that the viscosity varies linearly with temperature and that the Prandtl number is constant.

203. Motulevich, V. P. Evaluating terms of boundary layer equations. — InFZh no. 5 86-91

An attempt is made to obtain quantitative criteria for evaluation of various phenomena and their corresponding terms in a complete system of differential boundary layer equations, taking into account all the factors resulting from the molecular-kinetic theory of matter. Diffusion and energy equations are considered. The expression for the reference term is established and its selection procedure outlined for both equations. An approximate method is developed for calculating the dimensionless parameters of both equations, which makes it possible to determine the relative role of every separate term.

204. Kozlov, L. F. Optimum boundary-layer bleed on a porous plate in an incompressible fluid. InFZh v. 6, no. 10 88-92

The optimum suction of an incompressible fluid from the boundary layer on a porous plate is investigated theoretically. Laminar friction coefficients, and local and total amounts of removed fluid are determined.

205. Galkin, V. S. The effects of slip in hypersonic slightly rarefied gas flow past bodies. InZh v. 3, no. 1 27-36

The effects of slip on aerodynamic parameters of bodies in a hypersonic rarefied-gas flow and the limits of applicability of laminar boundary layer theory to the description of a viscous disturbed flow past plane and axisymmetric bodies are discussed. Expressions for slip-velocity and temperature jumps are derived and the terms of the Burnett equation along the wall are evaluated by using the local similarity method and self-similar solutions of the boundary layer equations.

206. Neyland, V. Ya., and G. I. Teganov. Supersonic separated flows. InZh v. 3, no. 2

A detailed study on the configurations of forward separated flow regions in supersonic flow past symmetric bodies is presented. The angle of flow separation is determined, and its dependence on Mach number is established for the case when the ratio of the viscous boundary-layer thickness on the interface of the conical separated region near the reattachment point to the radius of body curvature in the meridional cross section tends to zero.

207. **Bukovshin, V. G., and G. I. Taganov.** Determination of the aerodynamic forces acting on bodies with separation regions in hypersonic flows. — InZh v. 3, no. 2 215-221

A theoretical method is outlined for calculating the aerodynamic forces acting on bodies of arbitrary shape in hypersonic flows in the presence of separated flow regions of given configurations. The method is applied to the calculation of lift and drag for a sphere and a cone, both with a spike at an angle of attack.

208. **Koshmarov, Yu. A.** (Moscow). Rarefied gas flow along a wall suddenly set in motion. — InZh v. 3, no. 3 433-441

The dynamic behavior of a gas set in motion by a sudden movement of the gas-confining infinite plane is investigated on the basis of molecular theory and under the assumption that the velocity of the plane is smaller than the velocity of sound in the gas. An equivalent system of equations of moments is used instead of the Maxwell-Boltzmann equation for determining the function of molecular velocity distribution.

209. **Badyagin, A. A.** The maximum lift-drag ratio of an aircraft. — IzVUZ AvT no. 1 3-9

The effect of balancing (static stability) on the lift-drag ratio of a conventional and of a "canard" type supersonic aircraft is investigated.

210. **Khaldeyev, V. M.** The selection of optimal parameters of aircraft mechanisms. — IzVUZ AvT no. 1 66-79

An engineering method is described for the design of aircraft mechanisms which are to be set within a strictly limited contour. The particular case of a landing-gear mechanism is considered.

211. Sirazetdinov, T. K. Optimal problems of gasdynamics. IzVUZ AvT no. 2 11-21

A system of equations is derived for determining an optimum body surface having minimum drag or maximum heat dissipation (minimum heat flow into the body). The equation of a minimum-drag airfoil in supersonic flow is discussed in detail.

212. Vinogradov, B. S., and Z. G. Shaykutdinov. An approximate method for calculating the detached bow shock wave in supersonic flow past blunt bodies. IzVUZ AvT no. 2 60-64

An approximate method is outlined for rapid evaluation of the basic parameters of a detached bow shock wave and of flow behind it. It may be applied with sufficient practical accuracy to either plane or axisymmetric flows.

213. Dolomanov, Ye. G. The calculation of air parameters behind a normal shock with stagnation-temperature inversion taken into account. IzVUZ AvT no. 2 65-69

The flow parameters in the region of the stagnation point are calculated, taking the effect of temperature inversion into account. A graph-analytical method is used for calculating the gasdynamic and thermodynamic parameters of air; the effects of ionization, dissociation, NO-molecule formation, and variable specific heat are considered.

214. Sidorov, O. P. A certain class of vortex flows. IzVUZ, AvT no. 4 175-179

Hydrodynamic effects on flows which

exclude the formation of shock waves (specially selected vortex fields have this property) are investigated to the first approximation. A nonlinear system of gas dynamic equations describing a plane, steady flow of an inviscid, compressible gas is considered and after certain analytical transformations reduced to a linear system.

215. Vallander, S. V. (Editor). Soviet studies of rarefied gases (I), (II), and (III). — LU NIIMMe no. 1 1-267

216. Varzhanskaya, T. ., Ye. I. Obroskova, and Ye. N. Starov.. Boundary layer in the vicinity of a stagnation point. — MoUVychTs, Sb no. 2 135-145

An analytical investigation is presented of a compressible laminar air boundary layer near the stagnation point of a flat porous plate through which hydrogen is uniformly injected.

217. Golitsyn, G. S. Correlations in local isotropic turbulence. — PMMe v. 27, no. 1 61-74

A study of velocity correlations and pressure distributions is made on the basis of Kolmogorov's theory of locally isotropic turbulence. The statistical characteristics of the turbulence in the whole equilibrium range are calculated with the use of a spectral density mode which at high wave numbers decays like a Gaussian function. Where possible, these characteristics are compared with results obtained on the basis of other turbulence models, for example, models with constant asymmetry and Heisenberg modes.

218. Gonor, A. L. Three-dimensional minimum-drag bodies at high supersonic speeds. PMMo v. 27, no. 1 185-189

Supersonic flow around a conical body is analyzed and expressions for pressure and drag coefficients are derived. The drag coefficient formula is used to reduce the problem to the separate determination of optimal shapes for meridional and transverse sections. The calculations show that the optimal cross section is star-shaped. The possibility of determining the optimal transverse section of a body having one of its sides a plane parallel to the flow is indicated.

219. Kreyko, A. N. (Moscow). On the determination of minimum-drag bodies by use of the Newton and Buseman pressure coefficient laws. PMMe v. 27, no. 3 484-495

After reviewing a series of studies on determining the shape of bodies having minimum drag under certain types of restrictions, the author analyzes the same problem with various arbitrary restrictions.

220. Savulescu, S. N., and V. Toma. An experimental investigation of the interaction of a low-intensity jet with an incompressible boundary layer on a flat plate. StuCeMeAp v. 14, no. 5 1037-1063

The principal results of an experimental investigation of the transition of an incompressible boundary layer on a flat plate initiated by a low-intensity jet are presented. A brief description of the experimental setup is given.

221. Soloukhin, R. I. Detonation waves in gases. UsFN v. 80, no. 4 525-551

This review of 125 articles (88 Soviet) published in 1959-1963 on detonation waves in gases deals with: experimental methods for studying gas parameters behind a detonation front, characteristics of gas ignition behind a shock wave, transition from deflagration to detonation in gases, gas pulsations behind the detonation front, detonations in steady gas flows. Unsolved problems and prospective research are briefly discussed.

222. Baush, G. The small-parameter method in the hypersonic flow of an ideal gas past pointed bodies. VeLUMMeAs no. 1 86-89

The method of a small parameter is used for determining the hypersonic characteristics of flow of a perfect gas past plane and axisymmetrical pointed bodies. The method does not lead to a singularity at the zero-contour-pressure point.

223. Grib, A. A., G. Baush, and L. M. Vyaz'menskaya. Some special features of hypersonic gas motion. VeLUMMeAs no. 1 96-105

Flow past bodies of revolution and flat contours with arbitrary dependence of internal energy on pressure and temperature is detemined by a procedure based on the methods of G. G. Chernyy and G. A. Lyubimov. Some special features connected with the solution of the Mises equations in the form of a series are discussed.

224. Onufriyev, A. T. A model of nonequilibrium processes in continuum mechanics. ZhPMeTF no. 1 47-56

An attempt is made to construct a model of the transfer processes in some linear problems with one-dimensional transfer, considering the free-molecule flow. The concept of the mean free path is reviewed, and the flow of a rarefied gas past a semi-infinite plate is analyzed.

225. Romanenko, P. N., and V. N. Kharchenko. The effect of gas injection into a turbulent boundary layer on skin friction. ZhPMeTF no. 1 77-83

The boundary layer on a flat porous plate is experimentally studied in respect to the effect on its dynamic characteristics of injecting freon, CO_2, and air into it. A flow of heated gas with increasing and decreasing pressure gradients is considered. A detailed description of the experimental facilities and test procedure is presented. An approximate procedure is suggested for calculating the dynamic boundary layer in the case of turbulent gas flow with a longitudinal pressure gradient and transverse mass transfer.

226. Korobeynikov, V. P. (Moscow), P. I. Chushkin, (Moscow). Calculation of the initial stage of a point explosion in various gases. ZhPMeTF no. 4 48-57

A numerical solution of a linearized point-explosion problem with back pressure taken into account is considered in the cases of plane, cylindrical, and spherical waves in gases within a wide range of adiabatic exponent. A method is outlined for the solution of linearized blast-wave problems which is very convenient for computer calculations.

227. Adushkin, V. V. (Moscow), I. V. Nemchinov (Moscow). Approximate determination of gas parameters behind a shock-wave front for the prescribed law of shock propagation. ZhPMeTF no. 4 58-67

A method is outlined for approximate determination of gas parameters behind a shock-wave front from the given law of shock-wave propagation. The method is based on calculation of basic derivatives of gasdynamic parameters at the shock-wave front in Lagrange's coordinate system and consists of the linear extrapolation of pressure along the mass of gas in motion with respect to a known value of the pressure derivative at the wave front. The other parameters are calculated from gasdynamic equations.

228. Shidlovskiy, V. P. (Moscow). A problem of gas point-mass escape and its solution by means of the kinetic theory. ZhPMeTF no. 4 74-77

An unsteady motion of a monatomic gas, corresponding to the escape of a point mass into vacuum, was studied by means of the kinetic theory of flows on the basis of the solution of the Boltzmann equation in the case of nonequilibrium initial distribution. Collisions among the molecules themselves were neglected. The more general case of escape in the presence of a steady potential power field was also considered.

229. Adushkin, V. V. (Moscow). Formation of a shock wave and dispersion of explosion products into the air. ZhPMeTF no. 5 107-114

The law of motion of a shock-wave front and the explosion products from detonation of spherical charges of certain explosives in the air were investigated experimentally. The dependence of the shock-front basic parameters on the shock-front velocity is

established near the source point and at distances at which the Sadovskiy formulas are satisfied. The dependence of shock-layer thickness on distance is derived in the region of detonation-product action. A set of photographs of data obtained by a piezoelectric sensor is given. The pressure and density distribution in the region between the shock front and contact surface is obtained on the basis of experimental data by a method similar to the thin-layer method used by Chernyy.

230. Zaydel', R. M. (Moscow), and Ya. B. Zel'dovich (Moscow). One-dimensional instability and attenuation of a detonation. ZhPMeTF no. 6 59-65

Instabilities associated with perturbations causing distortion of the shock front were analyzed. In this detonation wave instability different temperatures are established in individual sections of the shock front and amplification of the perturbation results in the occurrence of ignition steps and collisions which in turn cause spinning detonation. In the present study, the stability of a detonation wave is considered with respect to the changes in the distance between the shock front and the chemical reaction zone.

231. Shugayev, F. V. Interaction of a supersonic stream with an obstacle. ZhPMeTF no. 6 101-103

An experimental investigation of the motion of a shock wave caused by the interaction of a supersonic stream ($M = 1.5$ to 1.65) in a shock tube with a cylinder. The shock wave velocity is determined and the duration of the transient motion is measured.

232. Anisimov, S. I., and Yu. V. Khodyko. Gas flow about the forward stagnation point of a blunt body with retarded excitation of vibrations. — ZhTF v. 33, no. 11 1333-1337

The gas flow near the stagnation point of a blunt body is studied in the velocity range where there is no appreciable dissociation behind a detached shock wave, in the presence of retarded excitation of vibrations.

233. Telenin, G. F., and G. P. Tinyakov. A method for three-dimensional analysis of flows around bodies with detached shock wave. — 1964 ~~DAN~~ SSSR v. 154, no. 5 1057-1058

A numerical method developed by the authors for integrating gas-dynamics equations to analyze supersonic flows around bodies with detached shock wave is extended to the case of three-dimensional flows with a detached shock wave. Some results of the calculations for ellipsoids of revolution are presented.

234. Generalov, N. A., S. A. Loscu, and A. I. Osipov. — DAN SSSR v. 156, no. 5 1057-1060

The distribution of vibrational energy of molecules of N_2 and O_2 and temperatures behind the front of a normal shock wave are determined with and without effects of vibrational quanta taken into account, by using a simultaneous system of equations of conservation of mass, impulse, and energy, also of equations of state and relaxation. The shock-wave velocities M = 5, 9, and 20 at an initial pressure of 1 mm Hg are considered.

235. Koshmarov, Ya. A. (Institute of Mechanics, Academy of Sciences USSR). On the rarefaction effect on gasdynamics surface friction when gas is injected or sucked through a wall. | InFZh v. 7, no. 6 48-54

The problem of steady flow of a rarefied Maxwellian gas between two permeable surfaces moving relatively to each other at a low speed is discussed on the basis of molecular motion.

236. Gozdovskiy, G. L. Yu. N. Ivanov, and V. V. Tokarev. The mechanics of low-thrust space flight. III | InZh v. 4, no. 1 168-196

This third part contains a discussion of the problems associated with limited-power propulsion systems — their optimum control, reliability in operation, and weight. Propulsion systems related to those of low thrust are also examined.

237. Pudoveyev, A. P. The supersonic analogy method for calculating one-dimensional unsteady gas flows. | IzVUZ AvT no. 2 81-87

The supersonic analogy method is extended to determining the quantitative relationships and calculating unsteady flows. A self-similar unsteady flow is compared with the Prandtl-Meyer flow. The relations obtained here can be used for determining the gas flow parameters for arbitrary boundary conditions up to the formation of a shock wave.

238. Romanenko, P. N., and V. N. Kharchenko. The effect of gas injection into a turbulent boundary layer with a longitudinal pressure gradient on skin friction. | ZhPMeTF no. 1 77-83

The results of an experimental investigation of basic dynamic characteristics of a turbulent boundary layer on a porous plate in a longitudinal hot-air flow with accelerating and adverse pressure gradients in the direction of flow are presented.

239. Pavlova, L. M. (Moscow), and Yu. D. Shmyglevskiy (Moscow). Boundary layer in radiating gas. ZhPMeTF no. 1 109-113

Plane and axisymmetrical flows of radiating gas in the boundary layer over plane surfaces (for example, a double-wedge airfoil, the plane front portion of bodies of revolution, et cetera) are discussed. The simplifications of the expressions for the flux of radiant energy (essentially facilitating the computations) are studied, and a criterional inequality for determining the validity of such simplifications is derived.

240. Korotkov, P. F. (Moscow). On Mach reflection of shock waves. ZhPMeTF no. 1 114-116

The self-similar problem of determining the configuration of shock waves in Mach reflection of a normal shock from a plane rigid wall (wedge) is discussed. The location of the Mach wave (relative to the incident shock) and its intensity at the wall are determined, as well as the reflection coefficient.

241. Gladkov, A. A. (Moscow). The effect of relaxation entropy layer. ZhPMeTF no. 1 116-117

Relaxation processes in a hypersonic flow of a inviscid, heat-nonconducting gas past a blunt-nosed body are examined, assuming that relaxation processes occur in the gas behind the normal shock wave.

The relaxation entropy layer parameters (pressure gradient density, gas velocity) are briefly discussed.

242. Zhilin, Yu. L. (Moscow). On the theory of an entropy layer. ZhPMeTF no. 1 118-120

The formation of an entropy layer accompanied with a distortion of the shock in a hypersonic flow of an ideal gas around slender pointed bodies is discussed. The point of origin of the entropy layer, the intensity of its growth, and its thickness are examined.

243. Belotserkovskiy, S. M., V. S. Sukhorukikh, and V. S. Tatarenchik. Determining the density distribution in three-dimensional gasdynamic flows by means of optical methods. ZhPMeTF no. 3 95-99

A method is proposed for investigations of three-dimensional gas flows by means of quantitative optical methods. Approximating functions which describe the density field, including the form of a shock wave front, are selected on basis of empirical data obtained by optical measurements. A system of linear equations is derived from which the density distribution around the obstacle and the shock-wave form can be determined.

244. Soloukhin, R. I. On detonation in a gas heated by a shock wave. ZhPMeTF no. 4 42-48

Experimental shock-tube data on the formation of detonation waves in mixtures of adiabatically heated inert gases, are given. The process of development of self-ignition in a shock-tube is discussed. Analytical

and experimental values of detonation-wave parameters are compared in graphs and diagrams.

245. Zaytsev, S. G., Ye. V. Lazareva, and A. P. Shatilov. Investigating the normal shock-wave reflection in a shock tube. ZhPMeTF no. 4 143-149

The apparatus and the method for investigating the normal reflection of a shock wave from a rigid wall are described. The state of gas behind the shock wave is determined for various Mach numbers (2 to 6) in carbon dioxide, nitrogen, and argon. The density field behind a reflected shock wave is studied.

GROUP A AEROMECHANICS OF HIGH-SPEED FLOWS

A-2 Aerodynamics of Bodies
Plates and Cylinders
Wedges
Wings
Airfoils
Wing-Body Systems
Blunt and Pointed Bodies
Slender Bodies
Lift-Drag Ratio

246. Donov, A. E. A flat wing with sharp edges in a supersonic stream. — 1939 IzAN MeMa no. 3 603-626

Translation: NACA Tech. Mem. No. 1394 (1956)

247. Gurevich, M. (Institute of Mechanics, Academy of Sciences USSR, Moscow). The lift of a swept-back wing. — 1946 PMM v. 10, no. 4 513-520

Translation: NACA Tech. Mem. No. 1245 (1949)

248. Krasil'shchikova, Ye. A. The effect of the wing-edges at supersonic speeds. — 1947 DAN SSSR v. 58, no. 4 543-546

Vibration of a thin, deformable finite-span wing moving at supersonic speed is discussed. The method described here for determining the velocity potential at any point of the wing and the normal-velocity component due to vibration is applicable to wing edges of arbitrary shape.

249. Krasil'shchikova, Ye. A. The effect of the wing edges of a vibrating wing moving at supersonic speeds. — DAN SSSR v. 58, no. 5 761-762

A supplement to the author's preceding article [248], is presented, and the solution is obtained in the form of an absolutely converging series.

250. Sedov, L. I., M. P. Mikhaylova, and G. G. Chernyy. The effect of gas viscosity and heat conductivity on the flow behind a — 1953 VeLUMMeAs no. 3 95-100

large curvature shock wave.

Supersonic gas flow past a body of revolution with a strong shock wave is discussed with the effect of viscosity and heat conductivity taken into account.

1954
PMMe
v. 18, no. 5
561-572

251. Aslanov, S. K. Low-supersonic flow of an ideal gas past a thin wedge.

A simplified method of determining the drag of a thin wedge in a supersonic flow with a detached shock wave is presented. The sonic similarity law is used to derive formulas for the drag coefficient of a wedge and of a double-wedge airfoil in cases of a detached and attached shocks.

1955
PMMe
v. 19, no. 3
359-362

252. Aslanov, S. K. Magnitude of a local supersonic zone in a supersonic flow of compressible gas past a wedge.

The influence of the wedge apex angle and of the flow velocity is shown.

PMMe
v. 19, no. 3
363-367

253. Yur'yev, I. M. On the linearized theory of supersonic gas flows past bodies of revolution.

An approximate final form solution of the linearized equation for axisymmetric supersonic gas flows is proposed. This proposed method is suitable for calculating parameters of flows around annular bodies of revolution and around the outer parts of such bodies.

254. Kogan, M. N. Theory of flow past bodies of relatively small aspect ratio. — 1956, ~~PMM~~, v. 20, no. 1, 87-94

The possibility of adapting conformal mapping to the solution of three-dimensional problems of flow past wings is studied in a more precise setting than the thin-wing theory.

255. Lunev, V. V. Laminar boundary layer of a compressible gas with large temperature gradients on a plate. — PM Me, v. 20, no. 3, 395-401

The temperature range considered includes the temperature of air dissociation. A method of successive approximations for determining the flow parameters is given for steady boundary conditions.

256. Aslanov, S. K. Drag of a curvilinear profile in a sonic flow. — PMMe, v. 20, no. 6, 756-760

Sonic flows past a wedgelike body at a zero angle of attack are studied. Various methods of solution are reviewed.

257. Belotserkovskiy, O. M. (Computing Center Academy of Sciences USSR, Moscow). Flow past a circular cylinder with detached shock wave. — 1957, ~~DAN~~ SSSR, v. 113, no. 3, 509-512

Translation: M. D. Friedman, NoB-131

258. Chernyy, G. G. (Moscow). Hypersonic flow past an airfoil with a slightly blunted leading edge. — DAN SSSR, v. 114, no. 4, 721-724

Translation: M. D. Friedman, No. C-112

259. Chernyy, G. G. (Moscow). Hypersonic Flow around a slender blunt cone. DAN SSSR v. 115, no. 4 681-683

Translation: M. D. Friedman, No. C-113

An approximate solution for hypersonic flow past a slender blunted cone is derived, and results are compared with experimental data. Mass concentration in the perturbed region is assumed to be located on the generated shock wave and moving with it.

260. Krasil'shchikova, Ye. A. Unsteady motion of a finite-span wing in a compressible fluid. DAN SSSR v. 117, no. 5 777-780

Three-dimensional motion of a compressible fluid due to unsteady motion of a finite-span wing immersed in an unbounded fluid, at rest at infinity, is investigated. The motion of the wing is assumed to be only slightly disturbed. The problem is linearized and the generally accepted assumptions of thin-wing theory are used.

261. Chernyy, G. G. Flow of an ideal gas around a body at hypersonic speeds. IzAN OTN no. 6 77-85

An analytical method is presented for calculating steady hypersonic flows around plane contours and axisymmetric bodies. The method is based on expanding gas dynamics equations in a special series in powers of a parameter $\varepsilon = (\gamma - 1)(\gamma + 1)$, where γ is the ratio of heat capacities, and is analogous, in principle, to the method of solving the equations of motion of a viscous fluid in boundary layer theory by expansion in series of powers of $N_{Re}^{-1/2}$, where N_{Re} is the Reynolds number.

262. Gonor, A. L., and G. G. Chernyy. Minimum-drag bodies at high supersonic speeds. IzAN OTN no. 7 89-93

Numerical quadrature is used to solve the variational problem of finding the minimum-drag body in an axisymmetrical flow. Two limiting cases are considered: 1) the angle between the tangent to the contour of the body and the direction of the incident flow is small (the pressure is very low), and 2) the pressure on the surface of the body is infinite; the transition from a cone to the optimal shape was found to decrease the drag by about 30 per cent.

263. Kadyrov, S. Motion of a finite-span wing at supersonic speed. IzAN OTN no. 8 35-40

The motion of a wing of arbitrary shape in a three-dimensional flow of an ideal compressible fluid moving faster than the critical speed is discussed. The Mach number is assumbed to be high enough for formation of a shock wave at the leading edge of the wing and the gas flow behind the shock wave is supersonic everywhere.

264. Kopzon, G. I. Unstable motion of a wing in a supersonic flow. PMMe v. 21, no. 1 136-141

The application of the Laplace transformation to the velocity potential makes possible the analysis of a general case of boundary conditions on the wing, with an arbitrary dependence on time.

265. Kogan, M. N. Minimum-drag bodies in a supersonic gas flow. PMMe v. 21, no. 2 207-212

The problem of determining the minimum

drag of wings and bodies in a supersonic gas flow is studied under the assumption of the linear theory. It is shown that there are surfaces for which the forces acting on bodies inside these surfaces can be expressed by values of the velocity potential on that surface.

266. Chushkin, P. I. The calculation of some sonic gas flows. PMMe v. 21, no. 2 353-360

The application of an approximate method to the problem of symmetric sonic gas flow around the nose of an ellipse or an ellipsoid of revolution is given, and its extension to the case of an arbitrary profile is presented.

267. Nikol'skiy, A. A. Annular bodies of revolution with minimum external wave drag in supersonic flow. TsAeGiI, Sb 56-63

The problem of determining the shape of an annular body of revolution with minimum wave drag on the outer surface is solved in linear formulation, and explicit drag formulas for minimum-drag bodies are obtained.

268. Dorodnitsyn, A. A. Relationship between the curvatures of a shock wave and the outer surface of an annular body of revolution. TsAeGiI, Sb 64-73

Supersonic flow past a barrel with a coaxial cylindrical hole is analyzed, and the curvature of the shock wave is determined in relation to the curvature of the outer surface. The shock-curvature value is necessary in determining the pressure distribution over the outer surface of the body of revolution.

269. Dorodnitsyn, A. A. Pressure-distribution analysis for bodies of revolution in a supersonic gas flow. TsAeGiI, Sb 116-126

A method for determining the pressure distribution over bodies of revolution based on approximate integration of equations of axisymmetric-flow characteristics is presented. In practical applications, this method is even simpler than the method based on linearization of equations of motion, and shows satisfactory accuracy in comparison with known exact solutions.

270. Aksenov, A. P. Laminar boundary on a cone in a supersonic flow. VeLUMMe As no. 3 13-28

Skin friction and surface temperature are determined by using integral momentum and energy equations, with heat radiation either neglected or taken into account. The Prandtl number is assumed to be a function of temperature only, and the viscosity is assumed to vary according to Sutherland's formula.

271. Aksenov, A. P. Turbulent boundary layer in supersonic flow past a cone with heat radiation taken into account. VeLUMMe As MMA no. 4 112-128

The surface temperature is determined and a general formula for the skin friction in an axisymmetrical steady supersonic flow of gas past a cone is given.

272. Krasil'shchikova, Ye. A. Unsteady motion of a finite-span wing in a compressible medium. 1958 IzAN OTN no. 3 25-32

This article deals with disturbed motion

of a compressible fluid caused by unsteady motion of a thin wing of finite span moving according to a given law. The boundary value problems are solved by a previously published method for unsteady plane-parallel motions of a fluid (Izvestiya AN SSSR, OTN MM, no. 2, 1954). Quadratures are employed here for solving problems involving all types of unsteady motion of a wing in which the speed of motion of the wing is essentially supersonic, neglecting the end effect and the effect of the vertex system behind the wing.

273. Shidlovksiy, V. P. Approximate method of calculating high-Mach number flow past two-dimensional forebodies. — IzAN OTN no. 3 156-162

The two-dimensional problem of supersonic flow of an ideal gas about a sharp-nosed semiairfoil at zero angle of attack is treated. It is assumed that the flow is adiabatic and that the entropy changes are due to the presence of a shock wave.

274. Chernyy, G. G. The effect of slight bluntness of a body on high hypersonic flow around it. — IzAN OTN no. 4 54-66

An attempt is made to extend the theory of high hypersonic flows aroung slender pointed bodies to cases in which the nose or leading edge of the body is slightly blunted. The study is limited to flow around profiles and bodies of revolution.

275. Gonor, A. L. (Moscow State University). Hypersonic flow around a cone at an angle of attack. — IzAN OTN no. 7 102-107

A study of hypersonic gas flow around a circular cone is considered. The method of G. G. Chernyy for solving two-dimensional axisymmetrical flow is applied, introducing a spherical coordinate system with transformation of the system of equations into series in a stream function expression.

276. Zheludev, P. I. Supersonic flow past slender bodies of revolution with fins and without fins. IzAN OTN no. 9 74-82

Supersonic flows past slender bodies of revolution with fins at an angle of attack are considered in accordance with slender body theory and a second-approximation solution is constructed for supersonic flow past arbitrary bodies of revolution. The second approximation produced results which were closer to experimental values than the first approximation in the case of cones with vertex angles less than 15 degrees.

277. Monakhov, N. M. Determining the circulation around a high-aspect wing in a sideslip. IzVUZ AvT no. 1 19-26

An integral equation for determining the spanwise distribution of the circulation around a high-aspect wing in a sideslip at any angle is derived on the basis of the Biot-Savart formula.

278. Ostoslavskiy, I. V., and T. A. Grumondz. (Moscow Aviation Institute). The connection between the generation of lifting force of a wing and the nature of the flow in the boundary layer. IzVUZ AvT no. 1 27-36

The determination of the relationship between the generation of lifting forces of a wing and the nature of the boundary layer flow is given. Some experimental results are presented.

279. Sirazetdinov, T. K. (Kazan' Aviation Institute). Vibrations of a wing of high aspect ratio in a subsonic flow. IzVUZ AvT no. 1 43-52

The derivation of integral differential equations for a wing of high aspect ratio oscillating in a subsonic flow is given. The solution is presented for small frequencies of oscillation.

280. Kostychev, G. I. On shapes of bodies with minimum wave drag. IzVUZ AvT no. 2 9-15

The shape of minimum-wave-drag bodies is determined for given flow parameters in cases of supersonic potential flow, a flow with an oblique shock wave, and a plane flow. In the latter case, the optimal form is a wedge.

281. Keldysh, V. V. (Moscow). The application of slender-body theory to the calculation of aerodynamic characteristics of small-span wings with wingtip tanks. PMMe v. 22, no. 1 126-132

The application of the theory of slender bodies to the calculation of the aerodynamic characteristics of small-span wings with wingtip tanks is discussed.

282. Belotserkovskiy, O. M. Flow past a symmetrical airfoil with a detached shock wave. PMMe v. 22, no. 2 206-219

Translation: J. Appl. Math. and Mechanics, v. 22, no. 1, 1958, 274-296.

A critical survey of previous studies and various approaches used in calculating flows past a symmetrical profile with a detached shock wave is presented.

A method is given for computing the pressure distribution over the body, the sonic line, and other parameters. An analogous procedure based on Dorodnitsyn's method is used for analyzing the flow around an axisymmetric body with a detached shock wave.

283. Shmyglevskiy, Yu. D. On supersonic minimum-drag airfoils. PMMe v. 22, no. 2 269-273

The problem of finding an airfoil with minimum wave drag in a supersonic gas flow is considered. It is shown that concave airfoils of minimum drag practically coincide with a wedge.

284. Bulakh, B. M. Nonlinear conical gas flow. PMMe v. 22, no. 6 781-788

Quasi-linear differential equations describing the gas motion are reduced to canonical form to yield a second approximation for the nonlinearized vortex-free steady conical flow of a gas. The method is applied to a gas flow around a cone.

285. Khaskind, M. D., and V. S. Khomenko. Constrained supersonic flow past an airfoil. PMMe v. 22, no. 6 815-818

A nonlinear two-dimensional problem of a steady, constrained supersonic flow of an isentropic gas past an airfoil with a sharp leading edge is studied. The boundaries of the flow are assumed to be straight and parallel and the airfoil is positioned asymmetrically relative to them.

286. Bulygina, Ye. V. (Novosibirsk Electrical Engineering Institute). Problem of a wing of given volume with minimum wave drag. PMMe v. 22, no. 6 826-828

The derivation of a solution for the problem of an airfoil with minimum wave drag, based on the linearized theory and using the variational method, is presented.

287. Carafoli, E. and M. Ionescu. (Institute of Applied Mechanics Rumanian Academy of Sciences, Bucharest). A general theory of triangular wings with a given pressure distribution is presented. StuCeMeAp v. 9, no. 2 267-284

288. Carafoli, E. and B. Horovitz. (Institute of Applied Mechanics, Rumanian Academy of Sciences, Bucharest). Mixed problems of triangular wings provided with a normal plate (cruciform wings) in a supersonic flow. StuCeMeAp v. 9, no. 4 819-832

Certain mixed problems in the case of high-speed homogeneous flow around cruciform wings were studied.

289. Carafoli, E. and A. Nastase. (Institute of Applied Mechanics, Rumanian Academy of Sciences, Bucharest). A study of thin triangular wings of forced symmetry in a supersonic flow. StuCeMeAp v. 9, no. 4 833-853

Thin triangular wings of forced symmetry governing the variation of incidence and, consequently, the vertical velocity over the wing were studied. The derived formula can be used to determine the aerodynamic characteristics for wings of natural symmetry.

290. Kulonen, L. A. Interaction between a shock wave and the boundary layer in the vicinity of the leading edge of a flat plate at high supersonic velocities with radiation taken into account. — VeLUMMeAs no. 2 172-188

An approximate solution is obtained for uniform velocity at zero angle of attack for the case when the heat transfer between the plate and the surrounding medium is determined by the Stefan-Boltzmann Law.

291. Marenkova, A. F. A slender wing in a supersonic flow confined by a wall. — VeLUMMeAs no. 4 125-138

The linearized problem is solved by Ye. A. Krasil'shchikova's method and by the special procedure of mirror reflection. Calculations of flow past a flat infinite-span wing and a rectagular wing confined by a wall are given as examples.

292. Belotserkovskiy, O. M. Computer Center, Academy of Sciences USSR). Flow past a circular cylinder with a detached shock wave. — Vych M no. 3 149-185

Translation: AVCO Research and Development Div Report RAD-9-TM-66, 1959.

Dorodnitsyn's general method for integrating first-order partial differential equations of the mixed type is applied to calculating the flow of a uniform supersonic or hypersonic stream past a circular cylinder.

293. Lyubimov, G. A. (Moscow State University). Steady flow of an infinitely conducting gas around a wedge. — 1959 ~~DAN SSSR~~ v. 126, no. 4 733-735

A study of the problem of steady, infinite, conducting gas flow around

a wedge for an arbitrary distribution of the magnetic field in relation to the flow is reported.

294. Shmyglevskiy, Yu. D. Bodies of revolution offering minimum drag at supersonic speeds. DAN SSSR v. 126, no. 5 958-960

The problem of finding a contour which offers minimum wave drag for a given speed (supersonic) of the incident gas flow is considered for cases in which the shock wave is attached. It is shown that the variational problem can be solved if the conditions on the shock wave are utilized, which prmits reformulation of the variational problem.

295. Dolapchiyev, B., and B. Sendov. (Institute of Mathematics, University of Sofia, Bulgaria). Symmetrical flow about a circular cylinder with two trailing vortices. Vortex trajectory and drag of the cylinder. DAN SSSR v. 128, no. 1 53-56

An exact solution is obtained for the hydrodynamic problem of symmetric flow about a circular cylinder with two trailing vortices, including determination of the vortex tr sctory and drag of the cylinder.

296. Gonor, A. L. High supersonic gas flows around conical bodies. IzAN MeMa no. 1 34-40

A supersonic flow with an attached shock wave past a conical body of a given surface is examined. A method is developed for solving the equations of motion in the form of series in powers of a small parameter $\varepsilon = (\gamma - 1)/(\gamma + 1)$, where γ is the ratio of heat capacities. The method is applied to analyses of flows past a triangular wing and an elliptical cone.

297. Grigoryan, S. S. On the motion of a slender body under the action of a strong shock wave. IzAN MeMa no. 1 165-166

The motion of a body struck by a strong shock wave is discussed, neglecting the disturbances caused by reflection and diffraction behind the shock front.

298. Vorob'yev, N. F. Unsteady motion of a finite-span wing in a supersonic flow in the case of a sudden change in velocity. IzAN MeMa no. 1 167-170

The motion of a thin wing at a small angle of attack in an infinite volume of gas is investigated in linear formulation under conventional assumptions of the thin-wing theory. A vertical wind gust is mentioned as a particular case.

299. Grodzovskiy, G. L. Favorable wing-fuselage interference at hypersonic speeds. IzAN MeMa no. 1 170-173

Configurations of a wedge-shaped fuselage with a triangular or a swept wing, a semiconical fuselage with a triangular wing, and a power-law shaped fuselage with a suitable wing are discussed. Systems were considered at $M \to \infty$ as slender bodies. The results obtained can be used for bodies of similar shape at high supersonic speeds on the basis of hypersonic similarity and stabilization of aerodynamic coefficients.

300. Slezkin, N. A. (Moscow). On the theory of gas flow between a shock-wave front and the surface of a blunted body of revolution. IzAN MeMa no. 2 3-12

Previous articles by the author (DAN SSSR, v. 54. no. 2 and no. 7, 1946) on

flow analysis between the shock wave and body are extended here to a body of revolution. Two ideas are utilized: to divide the flow not only into longitudinal layers, but also into transverse sections and to distinguish the Reynolds, Oseen, and Prandtl layers, and use linearized equations in passing from one section to another.

301. Zheludev, P. I. On supersonic flow past plane quasi-triangular wings of low aspect ratio. IzAN MeMa no. 3 202-203

An approximate method of investigating the above problem by finding the velocity potential (in the second approximation) close to the wing surface. An expression for the pressure coefficient over the surface is derived.

302. Lunev, V. V. Motion in the atmosphere of a slender blunted body at high supersonic velocities. IzAN MeMa no. 4 131-133

The effect of a strong entropy increase of the gas in a detached shock wave on the pressure distribution over a slender, blunted body is analyzed. It is shown that at Mach numbers larger than 20, the entropy increase has a marked effect on the pressure distribution, even far downstream from the body.

303. Gonor, A. L. The pattern of a bow wave in an asymmetrical high-supersonic gas flow around a pointed body. IzAN MeMa no. 5 117-118

The variation of the bow shock-wave angles (on the windward and leeward sides of a circular cone), depending on the angle of attack, the apex angle of the cone, and the Mach number of the

oncoming flow is calculated and experimentally verified. The analytical and empirical data, as well as the technique of the experiment are discussed.

304. Zheludev, P. I. (Moscow). Supersonic flow past winged bodies of revolution. IzAN MeMa no. 5 118-121

A study of supersonic flow past slender pointed bodies of revolution equipped with low aspect ratio wings is reported. An iteration method is used to determine the velocity potential in the second approximation, using the solution of the slender-body theory for the first approximation.

305. Myasnikov, V. P. Laminar boundary layer on a plate in a supersonic flow of a slightly rarefied gas IzAN MeMa no. 5 127-130

An investigation of the laminar boundary layer on a flat plate in the region of slip flow is presented, taking into account the interaction between the external flow and the boundary layer.

306. Bondarev, Ye. N., and M. Ya. Yudelovich. On the possibility of an increase in the base pressure behind a wedge in flight at supersonic speeds. IzAN MeMa no. 5 186

The method of H. Korst for the approximate calculation of the pressure at the base of a wedge is discussed. As the pressure at the base increases as the square of the Mach number, it rises to a level above that in the oncoming flow. This "base drag" has little effect on the total drag of the wedge, but may affect the heat flow in the vicinity of the base.

307. Myasnikov, V. P. Laminar boundary layer on a plate in a supersonic flow of a rarefied gas. — IzAN MeMa no. 5 127-130

The flow is investigated in its slip region, where the interaction between the outer layer and boundary levels is taken into account. Calculations show strong influence of rarefaction on surface friction and heat flux. In the case of heat insulation of the plate, the rarefaction of air does not affect the value of surface friction.

308. Bulygina, Ye. V. (Novosibirsk Electrical Engineering Institute). Minimum-drag supersonic wings with a given degree of stability. — IzVUZ, AvT no. 1 3-9

The problem of determining the shape of a three-dimensional wing with minimum drag (for given lift and stability) is reduced to the problem of minimum drag for the given moment at zero lift. Triangular and tapered wings are discussed in linear formulation.

309. Kiselev, O. M. (Kazan' State University). Construction of a body of revolution on the basis of a given velocity distribution. — IzVUZ, AvT no. 2 20-24

A study to determine the shape of a body of revolution in an infinite axisymmetric potential flow of incompressible fluid, on the basis of a given velocity distribution, is reported.

310. Strashinina, K. P. Flow of compressible fluids past bodies of revolution. — IzVUZ, AvT no. 2 33-38

Gas parameters are determined on the

surface of a body of revolution on the basis of fundamental physical laws and some physical considerations. The method may be used to determine pressure on the surface of the body by taking friction into account.

311. Sidorov, O. P. (Moscow Aviation Institute). Calculation of hypersonic flow past a cone. — IzVUZ, AvT no. 2 144-146

Steady axisymmetric flow around an infinite cone is studied. The velocity of the flow is assumed to be hypersonic; the solution is given in closed form, using the approximate equation for the velocity potential.

312. Bobrov, G. Ye. (Military Aviation Engineering Academy, Leningrad). Theory of annular wings in supersonic flow. — IzVUZ, AvT no. 3 3-8

The lifting force and the aerodynamic moments are determined for the internal surface of an annular wing in a supersonic gas flow in a linear formulation, using the distribution of pressures over the inner surface of the annular wing.

313. Mugalev, V. P. (Moscow Physicotechnical Institute). An experimental investigation of a subsonic turbulent boundary layer over a plate with injection. — IzVUZ, AvT no. 3 72-79

An experimental investigation of the subsonic turbulent boundary layer over a porous plate with gas injection is reported. The boundary layer flow was found to be analogous to flow over an impermeable surface in the case of a positive pressure gradient; a parameter determining the effect of injection on the boundary layer is discussed.

314. Vil'nit, L. N. (Novosibirsk Electrical Engineering Institute). The shape of a tapered wing which yields minimum wave drag for a given volume.

IzVUZ, AvT
no. 3
135-142

Procedures for determining the shape of a wing of trapezoidal plan form which will produce minimum wave drag for a given volume are studied.

315. Aleksakhin, B. N. Coefficients of lift and pitch moment for a combination of two slender bodies of revolution.

IzVUZ, AvT
no. 4
3-13

Aerodynamic coefficients of this combination of bodies are determined by the W. R. Sears' theory of slender bodies and by the method of conformal mapping. Applications of the method to calculating a combination of cone-nosed bodies are given.

316. Korobeynikov, N. P. Refinement of the slender-body theory for supersonic flow past bodies of revolution at an angle of attack.

IzVUZ, AvT
no. 4
26-31

An attempt is made to make G. N. Ward's slender body theory more exact by taking into account the effect of the Mach number. Relatively simple formulas are derived for calculating the Mach-number-dependent aerodynamic characteristics of slender bodies in a supersonic flow at an angle of attack.

317. Fomina, M. I. Characteristics of a geometrically twisted rectangular wing at supersonic speeds.

IzVUZ, AvT
no. 4
139-150

Coefficients of lift, drag, and moment of the wing in relation to its aspect ratio and geometric twist parameters are determined.

318. Kvashnina, S. S. and G. G. Chernyy. (Moscow), Steady flow of detonating gas around a cone. PMMe v. 23, no. 1 182-186

Discussion of a symmetrical steady flow of a detonating gas around a cone, based on the work of J. Ruthkowski and J. A. Nicholls, is presented.

319. Maykapar, G. I. (Moscow). Wave drag of a nonaxisymmetric bodies in a supersonic flow. PMMe v. 23, no. 2 376-378

Translation: J. App. M.M, v. 23, no. 2, 1959, 528-531.

Exact solutions are presented for cone shaped bodies of polygonal cross section and the effect of geometric parameters on the wave drag of such bodies in supersonic flow is determined.

320. Biryukov, Ye. A. (Moscow). Downwash behind a swept back wing of finite span during nonsteady motion. PMMe v. 23, no. 3 583-584

Formulas leading to a method for calculating the downwash in an ideal incompressible fluid behind a wing having a high aspect ratio and a small angle of sweepback are derived. The study covers the case when the circulation varying with span also varies harmonically with time.

321. Lunev, V. V. Flow of a viscous heat-conducting gas past a cone at high supersonic velocities. PMMe v. 23, no. 6 1006-1018

Flow past a circular cone at a zero angle of attack is analyzed. The flow conditions are studied at a sufficient distance from the nose of the cone so that the method of small perturbations may be applied.

322. Kovaleva, V. A. (Dnepropetrovsk). Unsteady motion of a rectangular plane wing. — PMMe v. 23, no. 6 1030-1041

The results from an investigation of the unsteady motion of a thin rigid wing of finite span and rectangular planform in supersonic flow, arbitrarily varying with time, including gust- or shock-wave-dependent unsteady motion, are presented.

323. Fedyayevskiy, K. K., and A. S. Ginevskiy. (Moscow). An unsteady turbulent boundary layer on an airfoil and on a body of revolution. — ZhTF v. 29, no. 7 916-923

The development of an approximate single-parameter method for determining the parameters of a turbulent boundary layer and the position of the separation point during acceleration of forward motion is discussed.

324. Ladyzhenskiy, M. D. On high supersonic gas flows. — 1960 ~~DAN~~ SSSR v. 134, no. 2 296-299

General equations of a steady high supersonic flow of a perfect gas are simplified (by giving various values to a certain velocity-vector parameter) for the flow past a slender body, and in solving the Cauchy problem for which the domain of definition of the solution is discussed.

325. Carafoli, E. (Institute of Applied Mechanics, Rumanian Academy of Sciences, Bucharest). Theory of simple and cruciform triangular wings in a supersonic stream. Part I. — InSb v. 27 17-28

Triangular wing systems are investigated — isolated wing and combinations of horizontal and vertical surfaces (such as the tail unit). The direct problem (determining the flight parameters of a given system) and the inverse problem (tailoring the shape of a system to given flight parameters) are discussed in parts I and II, respectively.

326. Krasil'shchikova, Ye. A. (Institute of Mechanics, Academy of Sciences USSR). Wings of finite span with a symmetrical profile in subsonic and supersonic flows. InSb v. 27 29-37

Some boundary value problems of a thin wing of finite span with a symmetrical profile in supersonic flow at an angle of attack are solved by the method proposed by the author.

327. Yur'yev, I. M. (Moscow). The calculation of bodies of revolution in a supersonic flow. InSb v. 27 38-44

Problems which are solved by means of linear second-order ordinary differential equations are discussed. These calculations are in agreement with calculations based on the theorems of Dorodnitsyn and Nikol'skiy.

328. Carafoli, E. (Head of Institute of Applied Mechanics, Rumanian Academy of Sciences, Bucharest). InSb v. 28 3-25

Part 2 of the article presents a theory of conical flow of a higher order, giving further development to include cruciform wings. It also deals with the problem of determining wing form as a function of a given distribution of pressure coefficients.

329. Iordanskiy, S. V., and Yu. D. Shmyglevskiy. (Computing Center, Academy of Sciences USSR, Moscow). Sublimation of an axisymmetrical blunt body near the stagnation point of an oncoming flow. InSb v. 28 26-35

Laminar boundary-layer equations for a subliming body are derived. A method for calculating the flow parameters and the sublimation rate is presented.

330. Yermolenko, S. D., and N. F. Vorob'yev (Novosibirsk). A comparison of finite span wing characteristics obtained experimentally with those calculated by using the linear theory of supersonic speeds. InSb v. 30 131-138

A study concerned with comparison of experimental results and those calculated on the basis of the linear theory of finite span wings is presented.

331. Bam-Zelikovich, G. M., A. I. Bunimovich, and M. P. Mikhaylova. (Moscow State University). Motion of slender bodies at hypersonic speeds. IzAN MeMa no. 1 33-40

The results obtained by Tsien Hsueh-shen for the case of three-dimensional flow in the presence of shock waves and vortices are generalized. A comparison of the results obtained with available exact solutions determined the limits of applicability of this method.

332. Lunev, V. V., I. N. Murzinov (Moscow), and O. N. Ostapovich. Hypersonic flow around blunted cones at small angles of attack. IzAN MeMa no. 3 121-125

The effect of bluntness on the pressure distribution over the generatrix of thin, blunted cones at large Mach numbers is discussed.

333. Korobeynikov, N. P. Supersonic flow at an angle of attack past triangular wings and elliptical cones with a subsonic leading edge. IzVUZ, AvT no. 1 28-34

A conformal mapping analysis is made of the flow past pointed, low-aspect-ratio lifting wings with a curved leading edge and past elliptical cones. The procedure is based on the solution of an arbitrary-generatrix body of revolution, obtained by employing the refined slender-body theory.

334. Bu[illegible]gina, Ye. V. Self-balancing of supersonic wings having a variable-sweep leading edge. IzVUZ, AvT no. 4 10-17

Self-balancing achieved by imparting a cylindrical curvature and geometrical twist to the median surface of the wing is analyzed.

335. Bobrov, G. Ye. On the feasibility of using aerodynamic interference to reduce the wave drag of annular wings in a supersonic flow. IzVUZ, AvT no. 4 3-9

The feasibility of using aerodynamic interference to reduce the wave drag of annular wings in a supersonic flow at zero angle attack is studied. The obtained solution, which is true for any values of the ring parameters and any values of the flow that satisfy the linear theory of supersonic flows,

represents a generalization of the results obtained by Utkin for the special case in which the trailing edge of an annular wing is not completely within the plane of the small-perturbation cone having its apex upon the leading edge.

336. Sychev, V. V. (Moscow). Two-dimensional hypersonic gas flows past slender bodies at large angles of attack. — PMMe v. 24, no. 2 205-212

Two-dimensional hypersonic flow about slender bodies is investigated. Approximate formulas are derived for calculating the aerodynamic characteristics of bodies at large angles of attack. Results can be applied to the case of wings of low aspect ratio and small relative thickness in hypersonic flow.

337. Belotserkovskiy, O. M. (Computing Center, Academy of Sciences USSR, Moscow). Machine computation of flow around axisymmetric bodies with a detached shock wave. — PMMe v. 24, no. 3 511-517

The development of a method for computer calculation of flow around axisymmetric bodies with a detached shock wave is presented. Results are given for certain simple bodies such as ellipsoids, spheres, and disks at various adiabatic exponents and Mach numbers $(1 < M_{\infty} < \infty)$.

338. Prituio, M. F. (Moscow). Streamline wings flying in presence of slip. — PMMe v. 24, no. 5 873-878

A method of determining the additional load on wings due to the presence of slip is presented. The technique is based on analysis of the linear equation

of the velocity potential. The case is considered in which, for $M > 1$, the small-parameter method leads in the second approximation to a solution with infinitely large first derivatives. Several problems involving streamline slip flow are solved as examples.

339. Shmyglevskiy, Yu. D. On a class of bodies of revolution with minimum wave drag. PMMe v. 24, no. 5 923-926

The shape of a generatrix of a body of revolution with a minimal wave drag is determined for a given velocity of the oncoming flow. The case of an attached shock wave is considered. Sample calculations for various M- are presented.

340. Gonor, A. L. (Moscow). Determining the shape of minimum-drag bodies for hypersonic speeds. PMMe v. 24, no. 6 1073-1078

A variational method for determining the shape of minimum-drag bodies in high supersonic plane and axisymmetric flows with a supplementary condition that the pressure at any point of the body contour must be non-negative.

341. Carafoli, E. and A. Nastase. Calculation of the surface of a supersonic wing furnished with a rib separating regions of different pressure distribution. Rev MeAp no. 1 5-20

The surface of a thin supersonic wing of triangular planform equipped with a rib which separates the two regions of different pressure distributions is determined. The cases of an arbitrarily and of a centrally located rib are considered.

342. Carafoli, E., and D. Mateescu. (Institute of Applied Mechanics, Rumanian Academy of Sciences, Bucharest). A general method of determining wing-fuselage interference in supersonic flight.

StuCeMeAp
v. 11, no. 1
11-48

343. Murgulescu, E. (Institute of Applied Mechanics, Bucharest). On the theory of conical flows in the case of a thin wing of given cross section.

StuCeMeAp
v. 11, no. 1
61-94

A unique method is developed for studying conical flows in the case of thin conical wings with given cross section. A brief survey of research done on the theory of conical flows is given. The boundary problems can be reduced to those of Dirichlet or Volterra. The case of conical wings with subsonic trailing edges is considered, taking account of the separation of a turbulent layer at the trailing edges.

344. Carafoli, E., and D. Mateescu (Institute of Applied Mechanics, Rumanian Academy of Sciences, Bucharest). Supersonic flow around a cruciform wing-conical fuselage system.

StuCeMeAp
v. 11, no. 2
325-337

A study was made of the flow around a wing-conical fuselage system equipped with a normal plate for the case of subsonic leading edges of the wing and plate, where the incidence of the fuselage differs from that of the wing and the normal plate. The study is based on the small perturbations hypothesis and it is considered that the dimensions of the fuselage are sufficiently small relative to the Mach cone and that the angle of incidence of the wing, the normal plate, and the fuselage are also sufficiently small.

345. Carafoli, E., and A. Nastase. A thin triangular wing with minimum drag in supersonic flow. | StuCeMeAp v. 11, no. 4 817-833

The planform of a minimum-drag, thin, asymmetric triangular wing equipped with a ridge separating the distribution w, which can be considered as the hinge of the leading edge slot is determined. Suction forces are included in the calculation of drag. The study is made within the limits of higher-order conical flows and uses a variational method of calculation.

346. Lunev, V. V. Hypersonic flow of a radiating gas past a wedge. | ZhPMeTF no. 2 40-46

Hypersonic flow past an infinite wedge is investigated under assumptions that the influence of radiation is small, and that it has no influence on the gas motion in front of the shock wave.

347. Yeletskiy, A. V. Flow of a gas with partial internal energy lag past a wedge. | ZhPMeTF no. 2 54-63

Works in this field are reviewed, and fundamental relationships are established for supersonic flows below 2000°K.

348. Grigor'yan, S. S. (Moscow State University), and V. Vani (Peking). Hypersonic flow of a perfect gas around an axisymmetrical body at small angle of attack. | ZhPMeTF no. 4 13-28

Chernyy's analytical method is applied to calculations of flows at small angle of attack. The method permits the linearization of the problem and its solution.

349. Karpenko, P. D. Determination of the pressure distribution over an airfoil in an incompressible fluid flow. | 1961 ~~Dop~~ An UkrSSR no. 12 1560-1566

A method of determining the parameters of flow of an incompressible fluid past a given airfoil with a salient point at the trailing edge by means of successive conformal mapping is discussed.

350. Ionov, V. P. Gas parameters at the surface of a cone. | EnI. AN SSSR FGaTp M. 1961 25-30

Approximate methods are presented for determining the parameters of a high-velocity gas flow at the surface of a cone. The flow is assumed to be axisymmetric, isentropic, and in thermodynamic equilibrium. At high velocities the oblique shock wave is very near the surface of the cone, thus there is only a small change of air-flow parameters between the cone and the shock wave.

351. Petrov, Yu. N. Supersonic flow about a plate in the presence of a boundary gas film. | EnI. AN SSSR FGaTp 81-88

Results are given of an experimental study of phenomena connected with longitudinal supersonic flow about a heat-insulated plate on whose surface a film of various cooling gases (air, nitrogen, hydrogen, and argon) was formed by tangential injection through a thin slit. Temperatures were measured by thermocouples, with errors not exceeding 0.3°C.

352. Nikol'skiy, A. A. Forces acting on a slender body in the vicinity of a blunted surface in supersonic flow under conditions of gas radiation. | InZh v. 1, no. 3 40-45

Hypersonic heating of a blunted slender body (plate or bar) is analyzed. The flow is divided into three regions: 1) stagnation H, where high temperatures are generated; 2) immediate vicinity of the body K, where all the streamlines have passed through H; and 3) turbulent region L, between K and the shock wave.

353. Bulakh, B. M. On the position of the bow shock wave in a supersonic gas flow past an arbitrarily shaped slender body. InZh v. 1, no. 3 158-160

By an asymptotic formula based on the author's previous work the position (and strength) of a forward shock wave formed in a supersonic gas flow past a slender body of arbitrary shape is determined.

354. Krasil'nikov, Yu. I. Aerodynamic characteristics of wings in supersonic flow in the presence of slip. InZh v. 1, no. 4 18-26

A study is made of plane, symmetrical wings at a small angle of attack and a given angle relative to the direction of the supersonic flow. It is assumed that the disturbance caused by the wing is small and that the flow satisfies all requirements of the linearized theory.

355. Kogan, M. N. Symmetry of load on minimum-drag wings. InZh v. 1, no. 4 132

A simplified calculation of a minimum-drag supersonic wing is presented. The load distribution on the entire wing is derived from the pattern of load distribution on the frontal area of the wing.

356. Ladyzhenskiy, M. D. Hypersonic flow past slender, blunted bodies. IzAN MeMa no. 1 150-151

The bodies are of an arbitrary cross section, and it is assumed that the whole mass of gas is concentrated in an infinitely thin layer behind the shock wave. The problem of the flow past the body is reduced to the equivalent problem of the unsteady motion of a gas displaced by a piston.

357. Fursov, M. K. Calculation of rotary derivative coefficients for wings at supersonic speeds. IzAN MeMa no. 2 89-96

The linear problem of vibration of a thin, flat wing in a supersonic potential flow is considered. The basic motion of the wing is rectilinear translational. Harmonic vibrations of infinitely small amplitude are superposed on this basic motion.

358. Telenin, G. F., and G. P. Tinyakov. Unsteady supersonic flow around a blunt conical body. IzAN MeMa no. 2 97-105

A comprehensive theoretical analysis is presented of unsteady supersonic flow of gas around a body composed of spherical and conical surfaces and subjected to plane angular oscillations about its center. On the assumption that the conjugation points of the spherical and conical surfaces are located in the supersonic region at all times, the flow around each surface is considered as a separate case, that is, a flow around a sphere and a flow around a cone.

359. Galkin, V. S. Investigation of a hypersonic flow of weakly rarefied, viscous gas past a flat plate. IzAN MeMa no. 3 18-21

The drag coefficient is established for a flat, semi-infinite, heat-insulated plate in a hypersonic flow. It is assumed that the region between the attached strong shock wave and the plate is formed by a nonviscous zone and a laminar boundary layer. The strong interaction of the shock wave and the layer is analyzed. The slip velocity is taken into account.

360. Minyatov, A. V. Calculating the base pressure in a supersonic flow past a body of revolution. — IzAN MeMa no. 3 32-39

The theory of base pressure in the supersonic flow past flat plates is generalized to cover flow past bodies of revolution. Methods are given for the calculation of pressures in the cases of turbulent and laminar flows. Experimental and theoretical data are compared.

361. Shveyko, Yu. Yu. Influence of a supersonic gas flow on the lower critical force of a cylindrical panel. — IzAN MeMa no. 4 14-19

The velocity effect of a supersonic flow of a compressible gas along the directrices of a shallow rectangular cylindrical panel under compression on its lower buckling force is investigated. The upper critical force is also determined and the relationship between the stream velocity and the buckling stress, as well as stability criteria for the panel are established.

362. Zheludev, P. I. Thin-wing theory. — IzAN MeMa no. 6 172-176

Supersonic flow past slender, sharp-nosed bodies of revolution is analyzed from the point of view of the thin-wing theory.

363. Korobeynikov, N. P. The calculation of the aerodynamic characteristics of thin, curved bodies and cambered wings. IzVUZ, AvT no. 2 35-46

Initial relationships for flow around slender cambered bodies obtained from previously published data (Korobeynikov, N. P. Supersonic flow around slender bodies with a curved axis. GKAT, Collected Articles, no. 15, 1959) are used to derive formulas for calculating the aerodynamic characteristics of cambered, low-aspect wings. The effect of aerodynamic twist (wash) on these characteristics is shown by practical examples.

364. Loytsyanskiy, L. G., and Yu. V. Lapin. (Leningrad Polytechnical Institute). The application of Karman's method for calculation of turbulent boundary layer parameters in a gas flow past a plate. LPoI, Tr no. 217 7-16

By using Karman's equation for turbulent flow and applying a simple asymptotic expansion, Karman's theory of an incompressible-fluid flow past a plate is extended to the case of a compressible-gas flow at large Mach numbers. The gas is assumed to be perfect and the flow is analyzed for two cases: with heat removal and without it.

365. Minostzev, V. B. Supersonic flow past axially symmetrical bodies flying at at angle of attack. MoFTI, Tr no. 7 110-123

The supersonic flow of an ideal gas past axially symmetrical bodies flying at an angle of attack has been investigated in the case when $M \gg 1$ and the isentropic exponent is constant. The theory is illustrated by the calculation of the gas flow past a cone and past a truncated cone with a groove.

366. Bulakh, B. M. Some problems in conical flow theory. PMMe v. 25, no. 2 229-241

Boundary problems in the theory of conical vortex flows are discussed, and the pattern of flow past a triangular wedge is established accurately. Specific points formed in coalescing nonvortex and vortex flows behind attenuating shock waves are defined.

367. Bulakh, B. M. Some properties of conical supersonic gas flows. PMMe v. 25, no. 3 478-484

The influence of a shock wave on a conical flow is investigated. The shock wave is produced in a uniform nonperturbed supersonic flow by a conical body located inside the Mach cone.

368. Lunev, V. V. A similitude law for thin blunt bodies in a hypersonic gas flow. PMMe v. 25, no. 6 1050-1059

A theoretical investigation of the similarity of hypersonic flow about thin flat plates and axisymmetric bodies with blunt leading edges or noses is extended to obtain the generalized similitude law for viscous and inviscid heat-conducting gas flows. Observations regarding similitude criteria for a perfect gas flow are included.

369. Barantsev, R. G., and Wu, Tsjen-yu. Forces and moments acting on bodies of revolution in a free molecular flow. VeLUMMeAS no. 3 77-92

Aerodynamic coefficients of convex bodies of revolution are calculated for an equilibrium free-molecular flow

with diffusion reflection of molecules from the surface of the body. Numerical calculations for a cone with a half-apex angle of 20° are included.

370. Baush, G. Supersonic flow of an ideal gas past plane, axisymmetrical, thin bodies. VeLUMMeAS no. 4 103-114

An approximate solution is obtained for the region between the shock wave and a body with a sharp leading edge. It is assumed that the shock wave is of small intensity. The method is an extension of G. G. Chernyy's method to the region of low hypersonic velocities.

371. Popova, I. A. (Leningrad State University). An approximate analytical solution of non-vortical equations for variable surface wing in supersonic flow. VeLUMMeAS no. 7 87-104

An approximate analytical solution of equations of a steady flow is obtained by the method of successive approximations, and the pressure and density on a wing surface in the absence of vorticity are determined.

372. Popova, I. A. (Leningrad State University). The effect of vorticity in supersonic flow around variable surface airfoils. VeLUMMeAs no. 13 131-145

Corrections to hydrodynamic parameters are given, with vorticity effects taken into account. The solution is a generalization of Donov's results for the profiles of some finite span wings.

373. **Borisov, B. I.** (Moscow State University). Minimum drag of an annular wing. VeMoU MMe no. 1 63

A method for determining the minimum-drag profile for an annular wing in supersonic flow is presented.

374. **Shugayev, F. V.** (Moscow State University). Supersonic flow around axisymmetric blunt bodies with detached shock wave. VeMoU MMe no. 2 46-53

The direct problem of the flow around blunted bodies of various shapes is discussed.

375. **Belotserkovskiy, O. M.** (Computing Center, Academy of Sciences USSR). Formulas and tables of values for supersonic flow about blunt bodies. AN Vych Ts 1-55

Formulas are given for determining flow fields about axisymmetric ellipsoids of revolution, including the sphere, in a supersonic flow of an ideal gas. A. A. Dorodnitsyn's method of integral relationships makes possible the direct solution of the problem of constructing the flow around a given body.

376. **Tirskiy, G. A.** A sweptback wing in hypersonic flow. ZhPMeTF no. 6 54-68

The problem of failure of the leading edge is discussed as an essentially three-dimensional one with a secondary flow in the boundary layer. The displacement of the ablated surface on the leading edge is taken into account. Two cases are analyzed in detail: when the material of the cylinder has a definite melting temperature and an arbitrary finite number of transient temperatures at which heat absorption occurs (metals and crystalline modifications of some ceramics

follow this disintegration pattern); and when the material does not have a definite melting point and there is exponential temperature dependence of the viscosity of the molten material (various glasses disintegrate in this way). A system of equations for the disintegration process and an approximate formula for the ablation rate of vitreous materials (case 2) are given.

377. Mishin, G. I., and V. A. Ovsyannikov. (Leningrad Physicotechnical Institute). The influence of gas-dynamic relaxation of CO_2 on the drag coefficient of a sphere at supersonic velocities.

ZhTF
v. 31
1467-1471

The results from measurements of the drag coefficient for a sphere for long and short relaxation times of deformation oscillations of a CO_2 molecule are presented. The influence of relaxation on the drag coefficient of a sphere is evaluated.

378. Belotserkovskiy, O. M., and P. I. Chushkin. Supersonic flow past blunt bodies.

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v. 14, no. 314
461-487

A numerical method is given for obtaining a solution of the exactly formulated problem of the supersonic steady flow of a nonviscous perfect gas around a blunted symmetrical profile and a body of revolution of arbitrary shape, both with zero angle of attack. Sample calculations for $M = 1$ to 10 and ∞ are presented.

379. Zhigulev, V. N. (Moscow). On the effect of the relaxation boundary layer.

DAN SSSR
v. 144, no. 6
1251-1254

The supersonic flow of a weak relaxation gas around a wedge is investigated. It is shown that the nonequilibrium effects

are essential not only in the layer adjacent to the shock wave, but also in a region called the "relaxation boundary layer" close to the surface of the wedge and extending infinitely downstream and having a thickness of several relaxation lengths. An exact solution is given for the oscillatory relaxation problem.

380. Kosterin, S. I., Yu. A. Koshmarov, and Yu. P. Finat'yev. Hydrodynamics of a turbulent air flow in the gap between rotating coaxial cylinders. — InFZh v. 5, no. 5 15-20

The air flow in an annular channel between a rotating inner cylinder and a stationary outer cylinder was experimentally investigated. The investigation covered the range of Reynolds numbers in the gap from 10^3 to 10^4 and of Taylor numbers from 0 to $5 \cdot 10^4$. The test setup and the measuring instrumentation are described in detail.

381. Krasil'nikov, Yu. I. (Moscow). Aerodynamic characteristics of a triangular wing with ailerons, flaps, and slots in supersonic flow. — InZh v. 2, no. 1 175-181

The problem of determining the lift, moment, and their coefficients for a thin triangular wing with a deflected aileron, open slots, and depressed flaps is reduced to evaluating a function of disturbed-velocity potential, and determining the distribution of the resultant pressure over the wing.

382. Nikolayev, V. S. Viscous hypersonic flow about a slender cone. — InZh v. 2, no. 3 9-13

A viscous hypersonic flow of an ideal gas over a slender cone at zero angle of attack is considered. The trans-

verse curvature of the surface and the interaction of the boundary layer with the shock wave are taken into account. Integral relations of impulses and energy are used in the boundary-layer calculations, assuming a constant surface temperature.

383. Bogacheva, A. A., and M. D. Ladyzhenskiy. Hypersonic flow around slender, elliptic, blunted cones. — InZh v. 2, no. 3 14-20

A hypersonic gas flow around slender, elliptic, blunted cones is examined under the assumption of infinite compression of the gas in the shock wave. The cone can be considered as a model of triangular wing with a very low aspect ratio.

384. Fridlender, B. I. Cruciform and T-shaped finite-span wings in a compressible fluid. — InZh v. 2, no. 4 245-261

The potential of disturbed velocity of a compressible gas is determined in a steady supersonic flight of thin cruciform and T-shaped wings similar to a tail unit of an airplane. Each plane has a different plan view. The wing-tip effects are discussed in detail for both wings.

385. D'yakonov, Yu. N., and V. G. Pirumov. Supersonic gas flows with dissociation and ionization. — IzAN MeMa no. 1 7-14

An approximate method for calculating supersonic flow about a wedge and a cone is presented. Two types of flow are considered: A Prandtl-Meyer flow in which complete thermodynamic equilibrium

of the gas is assumed and a frozen Prandtl-Meyer flow. Some speculations on the effects of thermodynamic and chemical disequilibrium on this flow are therefore possible. Equations are also presented for the flow about a cone at zero angle of attack, assuming perfect thermodynamic equilibrium of the gas behind the shock wave.

386. Kolodochkin, V. P. (Moscow). Pointed bodies of revolution in a supersonic flow at various angles of attack.

IzAN MeMe
no. 1
15-24

Properties of a supersonic axisymmetrical air flow over bodies of revolution with conical noses at a small angle of attack are discussed. Equations for characteristics of the resultant flow are obtained by superposition of disturbances on the basic (undisturbed) flow at $M_\infty = 1.5$ to 6.

387. Karafoli, Ye. (Carafoli, E.). Pressure distribution on airfoils in supersonic and hypersonic flows.

IzAN MeMa
no. 1
59-65

Expressions are derived for positive and negative pressure distributions over an airfoil; the positive—as the result of compression behind the shock wave (assuming that the velocity there is supersonic), and the negative—of the Prandtl-Meyer expansion over the whole range of reach numbers up to $M_\infty \rightarrow \infty$. Formulas are also given for the lift, drag, and moment coefficients.

388. Stulov, V. P. Flow over a convex angle of an ideally dissociating gas with nonequilibrium taken into account.

IzAN MeMa
no. 3
4-10

The problem is solved approximately for an arbitrary angle in the vicinity

of its apex. Consideration is also given to variations in discontinuities of normal derivatives of gas-dynamics variables along the characteristic curve separating the uniform incoming flow from the rarefied flow.

389. Lunev, V. V. (Moscow). Similitude conditions for hypersonic turbulent boundary layers on slender bodies. IzAN MeMa no. 4 13-17

Similitude conditions for hypersonic flows around plane and axisymmetrical slender bodies with a turbulent boundary layer having a variable entropy along its outer interface are investigated.

390. Mel'nikov, D. A. Supersonic flow around triangular flat plate. IzAN MeMa no. 6 33-39

A study is made of supersonic flow over a compressible surface of a triangular flat plate at an angle of attack at which the supersonic component of the velocity vector of an undisturbed flow normal to the leading edge meets the plate at an angle smaller than the limiting angle of the corresponding wedge.

391. Kholyavko. V. I. Flow about plates at high supersonic velocities. IzAN MeMa no. 5 26-31

The similarity between high supersonic flow past bodies and phenomena of an explosion wave is considered. On this basis, approximate solutions of supersonic flow past a blunt body may be obtained.

392. Lunev, V. V. Shock layer method in problems of hypersonic flow over slender blunted bodies. — IzAN MeMa no. 6 146-147

An analysis is presented of the method proposed by H. Cheng, T. Hall, T. Collian, and A. Hertzberg for approximate calculation of a flow over slender blunt bodies. An equation establishing the relationship between shock-layer thickness and pressure is given. Reasons for the discrepancies are given, and it is stated that the method used by G. G. Chernyy is more accurate in this case.

393. Aslanov, S. K. Sonic motion of a diamond-shaped airfoil at zero angle of attack. — IzVUZ, AvT no. 1 3-10

The sonic, steady-state, planar flow of a compressible gas past a diamond-shaped airfoil of a wing of infinite span at zero angle of attack is investigated. In the subsonic region, this investigation is based on Chaplygin's exact equation of flow and can serve as a standard for evaluating the accuracy of previous investigations made on the basis of the approximate equation of transonic flow.

394. Tumashev, G. G., and O. V. Troyepol'skaya. (Kazan' State University). Determining the shape of the jet of a wing with a jet flap. — IzVUZ, AvT no. 1 32-37

The shape of a jet formed by steady potential flow of an incompressible fluid around a thin, slightly bent wing equipped with a jet flap is determined. A small angle of attack and a small angle of inclination of the jet are assumed.

395. Drakin, I. I. Determining the optimum geometric parameters of aircraft structure. — IzVUZ, AvT no. 1 66-74

An analytical method is presented for determining the optimum shape and dimensions of aircraft structural members. The initial gross weight is taken for the optimality criterion under the assumption that no change in useful load and performance is associated with the variation in geometry. The optimum wing loading for a given speed and height of flight, and the optimum fineness ratio of the front portion of a fuselage are determined as examples.

396. Bulygina, Ye. V. Optimally cambered and twisted wing in supersonic flow. — IzVUZ, AvT no. 3 12-16

The balance of wings is achieved within a wide range of lifting forces without increasing the drag through suitable twist and camber.

397. Monakhov, N. M. Applying the Riemann method to solution of problems in flows past slender bodies. — IzVUZ, AvT no. 4 27-35

The potentials of disturbances of longitudinal and transverse flows are obtained at the generatrices of slender bodies of revolution at a small angle of attack.

398. Lunev, V. V. Hypersonic flow past slender, blunted power-law shaped bodies. — PMM v. 26, no. 2 389-390

The hypersonic-similarity laws for flows past thin, blunted cones and wedges have been established by G. G. Chernyy. It is shown that analogous laws can be applied to thin and axisymmetric bodies whose shape is described by a power function.

399. Bulakh, B. M. Supersonic flow around an inclined circular cone. — PMMe v. 26, no. 2 300-307

An analysis of supersonic flow about a cone at an angle of attack which reconciles the findings of Stone, Ferri, and Willet is presented.

400. Galkin, V. S. Lift in a free molecule flow. — PMMe v. 26, no. 3 567

A calculation is presented demonstrating that the lift of some bodies of finite length in a free molecule stream can be negative at any angle of attack between zero and 90° and for any value of the criterion $\mathcal{S} = V/c$ (where V is body velocity and c the most probable thermal velocity of incident molecules) even when the forces act on the body bases. The problem is calculated for flow past a symmetrical finite-length wedge where the ratio of the temperature of reflected molecules to the static temperature of the incident flow is in the range 0.1 to 1.

401. Bulakh, B. M. On asymmetric hypersonic flow around a circular cone. — PMMe v. 26, no. 5 973-976

A steady inviscid homogeneous hypersonic gas flow at angle of attack

past a circular cone is discussed. The velocity components on the cone surface are obtained by a modification of the A. L. Gonor solution presented in IzOTN, 1959, no. 7.

402. Shebalov, A. N. Wave drag of plane body in unsteady motion under a free surface. PMMe v. 26, no. 6 1104-1111

The problem of unsteady motion of a plane body of arbitrary shape under the free surface of a heavy, incompressible fluid is investigated, and a method for obtaining expressions for complex velocities and acting forces is presented. A Laplace equation is used to determine velocity potential. Special cases of the peculiarities of unsteady motion, such as plane vorticity and its sources, are examined and analyzed. An expression for the wave resistance of a body of arbitrary shape is established by using the formulas obtained by L. N. Sretenskiy. A wave-resistance formula for a cylinder of a certain radius in unsteady motion and submerged to a certain depth under the free surface is derived. This formula is found to be analogous to that of Sretenskiy.

403. Carafoli, E., and A. Ghia-Nastase. (Institute of Applied Mechanics, Bucharest). Minimum drag problem for a wing of symmetrical thickness. StuCeMeAp v. 13, no. 1 11-24

The problem of finding the surface configuration of a minimum-drag wing of asymmetrical-triangle planform symmetrical thickness, and a given volume is treated. The results obtained can be applied to determining the minimum drag of rectangular and trapezoidal wings.

404. Carafoli, E., and D. Mateescu. (Institute of Applied Mechanics, Bucharest). Wing-fuselage interference in high-order conical flows. StuCeMeAp v. 13, no. 2 275-294

The interference between wing and conical fuselage in a supersonic flow is analyzed in the case when the distribution of the angles of attack (or of incidence) is given as a sum of homogenqous polynomials of various orders, assuming that regions with different angle-distribution regimes are separated bv ridges.

405. Sandulescu, S. and A. Nastase-Ghia. (Insitute of Applied Mechanics, Bucharest). The mixed problem of a triangular wing in higher-order conical flow. StuCeMeAp v. 13, no. 5 1099-1126

The distribution of the angles of attack and pressures over the wing surface is determined from their distributions along two wing sections given by homogeneous high-order polynomials. The sections are divided from each other by a straight line (called "mixing edge") passing through the apex of the wing. The flow past triangular wings, thin and symmetrically thick, is investigated. By placing the "mixing edge" on the left or right side of the triangle, the direct and inverse problems can be obtained as limiting cases of the mixed problem.

406. Mateescu, D. (Institute of Applied Mechanics, Bucharest). Wings with sharp edges in supersonic flow. StuCeMeAp v. 13, no. 5 1127-1156

A special class of wings with all edges having zero thickness (called "wing with subtending surfaces") is

discussed. The supersonic flow past a triangular wing (thin and of symmetrical thickness) with subtending surfaces is analyzed and the problem of a triangular wing with a diamond-shaped profile is treated as an example.

407. Belova, A. V., and V. P. Loshkina. A thin airfoil in supersonic flow with complex thermodynamics. VeLUMMeAs v. 7, no. 2 96-100

A thin airfoil in a supersonic flow under complex thermodynamic conditions is considered and equations of motion are established in the first and second approximations. Formulas for calculating the lift components of the airfoil are also given.

408. Mikheyev, A. S. (Leningrad State University). An analytical solution to the problem of supersonic flow about conic surfaces. VeLUMMeAs v. 7, no. 2 105-112

The supersonic steady flow of gas about a cone is considered and an attempt is made to derive an analytical approximate solution which would be independent of the thickness of the body and the magnitude of the Mach number of the flow and would apply to gases, other than an ideal one, with a constant heat capacity.

409. Smirnov, N. V. Supersonic conical flow under complex thermodynamic conditions. VeLUMMeAs v. 7, no. 2 113-118

An analytical solution is given for the problem of supersonic isentropic flows of an arbitrary gas over a

single airfoil and over a cascade of airfoils. The problem is solved in the first and in the second approximations with the use of linearization.

410. Arkhipov, V. N. and K. S. Khoroshko. (Moscow). A method of accounting for relaxation in flow past a cone. — ZhPMeTF no. 6 121-124

The disturbance and relaxation of thermodynamic equilibrium in the supersonic flow of a mixture of perfect gases (with regard to chemical reactions only among components) past a fixed semi-infinite cone is discussed. Flow is parallel to the cone axis, and the disturbance is caused by gas compression when the gas passes through an attached shock wave.

411. Chuskin, P. I. (Computing Center, Academy of Sciences USSR, Moscow). Hypersonic flow past blunted bodies of revolution. — ZhVychMMF v. 2, no. 2 255-277

The results of computer calculations, carried out by the method of characteristics, of the axisymmetric hypersonic flow of a perfect gas past blunted circular cones and cylinders are analyzed.

412. Babayev, D. A. Numerical solution of the supersonic flow past a delta wing. — ZhVychMMF v. 2, no. 2 278-289

The supersonic flow of a perfect gas past a plane delta wing with a positive angle of attack is studied. The boundaries of the region of influence of the wing apex on the upper part of the wing are determined.

413. Nazarov, G. I. Pressure of a gas jet on an isosceles wedge. | ZhPMeTF no. 1 25-33

Bergmann's method is used to solve two problems of pressure determination on isosceles wedges: 1) the symmetrical flow of gas over a wedge, and 2) the flow of a compressible fluid over a wedge at the inlet of a channel. In the second problem, some use is made of N. Ye. Zhukovskiy's formulas for the flow of incompressible liquids over wedges.

414. Murzinov, I. N. The effect of the Prandtl number on flow around a blunt body at low Reynolds numbers. | ZhPMeTF no. 1 39-43

The equilibrium flow of a viscous, fairly rarefied gas in the region of the stagnation point of axially symmetric blunt bodies moving at high supersonic speed is considered, and equations of continuity, motion, and energy are derived. The variation of the Prandtl number along the boundary layer and heat flow at the stagnation point are discussed in relation to wall temperature.

415. Sychev, V. V. Small disturbance method in problems of hypersonic gas flow over slender blunted bodies. | ZhPMeTF no. 6 50-59

An approximate solution of the problem of a uniform hypersonic gas flow past slender bodies with blunted noses is presented by using a unified small-disturbance method. Expressions are obtained for determining the flow parameters at a great distance from the body and in a layer close to its surface.

416. Babayev, D. A. Numerical solution of supersonic flow past a delta wing. ZhVychMMF v. 2, no. 6 1086-1101

The solution of a supersonic flow past the lower surface of a delta wing is studied in the domain of the influence of the wing vertex. Determination of flow parameters, entropy function, and the form of the shock wave is reduced to the solution of a system of corresponding equations of motion and continuity under certain boundary conditions.

417. Kuznetsov, S. T. Diagrams and tables of the flow about a wedge, cone, and concave surface of dissociated air.

This book contains diagrams and tables of dissociated air flow for calculating shock wave parameters of high-energy flows having velocities from 2000-10000 m/sec, and for heights from 0 to 80 km.

418. Nowak, Eugeniusz. Free molecule hypersonic flow past a sphere. 1963 ~~Arch~~ MeSt v. 15, no. 3 347-357

Free-molecule approximation of a steady hypersonic gas flow past a sphere is considered. Distributions of mean velocity of rebounded molecules are discussed, disregarding intermolecular collisions.

419. Fridlender, B. I. A cruciform wing of finite span in a compressible flow. DAN SSSR v. 151, no. 6 1299-1302

A thin cruciform wing in a supersonic flow, with its horizontal and vertical surfaces performing arbitrary harmonic

oscillations, is discussed. A linear formulation is used to derive an expression for the disturbed-velocity potential, considering the interaction of oscillations and the wing-tip effect. The way of handling the "cruciform" wings with arbitrary dihedral angles (e.g. star-shaped) is indicated.

420. Magomedov, K. M. Supersonic flow past blunt bodies with known sonic points. — IzAN MeMa no. 1 111-117

The flow field in the region between a detached shock wave and an axisymmetrical body with a known sonic point is studied in the case of a supersonic flow at zero angle of attack. The shape of the shock and the pressure distribution over the body are determined. Approximate formulas are derived for shock detachment, pressure distribution, and velocity gradient, depending on the ratio of shock densities ahead of and behind the normal shock, and on the bluntness parameters.

421. Grodzovskiy, G. L. (Moscow). Supersonic flow with a subsonic axial velocity component about a flat cascade and a perforated wall. — IzAN MeMa no. 4 115-120

Supersonic flow about a flat, periodic cascade with no separation having a subsonic axial component of the incident flow in a direction normal to the cascade-plane is considered. Expressions for basic flow parameters are established which take pressure losses into account. The flow fields both in front of the cascade and far upstream are studied.

422. Ozerinin, V. N. The effect of wing downwash on stabilizer lift. — IsVUZ.,AVT no. 1 157-166

An approximate method is presented

for determining the lift characteristic of a stabilizer with a span greater than that of the wing. An expression for the vertical component of the induced velocity at $M > 1$ is derived and the downwash behind a wing and a wing-cylindrical body combination is discussed.

423. Bulygina, Ye. V. A self-balancing airfoil of minimum drag. — IzVUZ, AvT no. 2 118-123

The problem of determining the shape of an airfoil of minimum drag with given lift and moment coefficients in an ideal fluid at high supersonic speeds is presented.

424. Bulygina, Ye. V., and L. T. Yakubo. Hypersonic airplane with self-balancing surface. — IVUZ, AvT no. 3 3-10

The problem of determining the lifting surface of a hypersonic airplane with a high lift-drag ratio and a known center of gravity is studied. The minimum-drag body problem with a given lift is treated in detail for given and arbitrary volumes of the body.

425. Kholyavko, V. I. Aerodynamic characteristics of airfoils and wings with blunted leading edges at high supersonic speeds. — IzVUZ, AvT no. 3 43-50

The plane supersonic flow of an inviscid perfect gas over slightly blunted bodies is examined by applying the principle of plane sections. The piston theory is used in deriving

the equations for shock wave propagation and pressure on the piston (body). The influence of edge bluntness and of the sweepback on the aerodynamic characteristics of a plate and triangle wing is discussed.

426. Val'kov, Yu. A. Entry of a winged aircraft into a vertical gust. IzVUZ, AvT no. 4 3-14

Longitudinal motion of a winged aircraft (treated as a perfectly rigid, constant-weight body) which has flown into a strong vertical current is analyzed, assuming that the directions of gust and of flight are always perpendicular to each other, and the gust velocity is small in relation to that of the flight. Expressions for determining dangerous gust velocities for various gust patterns are derived.

427. Romishevskiy, Ye. A. (Moscow). Hypersonic gas flow past slender bodies, with radiation taken into consideration. InZh v. 3, no. 1 12-17

Special features of high supersonic gas flow past slender bodies, whose form is described by a power or an exponential function, are discussed. The entry of such a body into dense layers of the terrestrial atmosphere is analyzed, and the radiation effect on the distributions of temperature, pressure, and velocities over concave and convex bodies is pointed out.

428. Bazzhin, A. P. Supersonic flow around a flat plate with detached shock wave. InZh v. 3, no. 2 222-226

A study is presented of the flow past a flat plate at an angle of attack with

a detached shock in the entire supersonic and hypersonic regions. The method of integral correlations is used for calculating flow parameters and computer programming of the flow-field configuration. The location of the critical point on the plate is examined under certain conditions. Numerical calculations were made at M = 4.5, 6.85, 10, and 20; at angles of attack of 90°, 75°, 65°, and 45°; and compared with experimental data.

429. Moiseyenko, A. F. Reversibility theorem for steady motion of an annular wing with fuselage. — InZh v. 3, no. 2 355-362

The reversibility theorem is applied to a combination of an annular wing and a coaxial infinite cylinder in steady subsonic or supersonic flow. Aerodynamic characteristics and pressure relationships of annular wings in direct and reverse flow are discussed and the lift-pressure relation is established. Lift characteristics of the wing-fuselage system are calculated for various wing-aspect ratios and ratios of cylinder to wing radii and are shown in graphs.

430. Neyland, V. Ya. (Moscow) and G. I. Taganov (Moscow). Forward separated flow region in nonsymmetrical supersonic flow over a spiked cone. — InZh v. 3, no. 3 419-423

A generalization of the method used by S. M. Bogdonoff and T. E. Vas (Hypersonic Separated Flows. Seventh Anglo-American Aeronaut. Conf., N.Y., 1959) to solve the problem of hypersonic separated flow over a spiked cone at an angle of attack other than

zero is described. The results (given in graphs) with respect to the maximum value of the angle of attack compatible with the flow model considered are discussed.

431. Neyland, V. Ya. (Moscow). Hypersonic inviscid gas flow over a plate at an angle of attack. InZh v. 3, no. 3 424-426

A method is outlined for calculating the parameters of an inviscid gas flow. The correlations of the flow theory of an inviscid gas makes it possible to determine the one-parameter class of solutions at given values of angle of attack and M of the incident flow. Numerical results are obtained for laminar flow in the mixing region with no heat transfer under the assumptions that the product of the density and the dynamic coefficient of viscosity is constant across the mixing region and that the Prandtl number is equal to 1.

432. Golubinskiy, A. I. (Moscow). Lift and moment of a thin airfoil in an arbitrary unsteady flow. InZh v. 3, no. 3 442-445

Unsteady subsonic and supersonic flows over a thin airfoil are considered in linearized formulation. The reverse-flow theorem is generalized to the case of an arbitrary unsteady flow by using the analogy with a steady flow over an equivalent three-dimensional wing.

433. Filippov, I. G. (Moscow). A theory of diffraction of weak shocks around wedges. PMMe v. 27, no. 1 75-84

A new method is used to study the general problem of two-dimensional weak-shock diffraction around wedges and bodies of arbitrary shape. With this method, the plane nonsteady flow-diffraction problem is reduced to the auxiliary problem of three-dimensional steady supersonic flow around bodies at an angle of attack.

434. Sapunkov, Ya. G. (Saratov). Hypersonic flow past a circular cone at an angle of attack. — PMMe v. 27, no. 1 190-192

The determination of the hypersonic flow properties around a circular cone at an angle of attack is determined by using Cheng's expansion of the small parameters. Error analysis indicates that the solution obtained by this method is not valid in the vicinity of the cone surface, which may be due to erroneous calculation of entropy.

435. Sapunkov, Ya. G. (Saratov). Hypersonic gas flow past a circular cone at an an angle of attack. — PMMe v. 27, no. 5 930-939

A method of successive approximations (by using the Poincare-Lighthill-Kuo method) is presented which uniformly approximates the exact solution of the problem of a hypersonic flow of a homogeneous gas around a cone at at an arbitrary angle of attack in the whole region between the shock wave and cone surface, including the vorticity layer.

436. Bulakh, B. M. Asymmetrical hypersonic flow past a circular cone. — PMMe v. 26, no. 5 973-976

A steady, uniform, inviscid flow of gas at an angle of attack is studied, and solutions similar to those of H. K. Cheng are obtained. It is shown that A. L. Gonor's theory cannot be applied in this case.

437. Ginzburg, I. P., and G. V. Kocheryzhenkov. Turbulent boundary layer in a compressible fluid on a thermally noninsulated wing or axisymmetric body. VeLUMMeAs no. 2 86-98

An approximate solution is presented for the problem of motion of a compressible fluid in a turbulent boundary layer on a thermally noninsulated wing or an axisymmetric body. The calculation procedure is outlined for a numerical example of a spherical body in an air flow of M = 20 with a stagnation point temperature of 7000°K.

438. Mikheyev, A. S. Supersonic flow around a body of revolution. VeLUMMeAs no. 2 120-127

A supersonic flow around a pointed body of revolution with a curvilinear generatrix is studied, and a system of gasdynamic equations describing a steady adiabatic gas flow with arbitrary thermodynamic properties is considered. The equation of a shock wave is derived, and gasdynamic parameters of the shock wave and on the body surface are determined.

439. Vereshchagina, L. I. Base pressure on bodies of revolution in a supersonic gas flow. VeLUMMeAs no. 3 139-143

A method for determining the base

pressure on bodies of revolution rotating in a supersonic gas flow (turbulent mixing) is presented. The model used is described, the flow in the mixing region is analyzed, and the procedure of calculation is given.

440. Perepukhov, V. A. Rarefied gas flow about a plate. ZhVychMMF v. 3, no. 3 581-583

A flow of highly rarefied gas about a flat circular plate at a zero angle of attack was analyzed. It was assumed: 1) that the macroscopic velocity of the flow is higher than the thermal velocity of the free-stream molecules and greatly exceeds the velocity of the reflected molecules, 2) that the reflection of molecules from the surface takes place by diffusion according to the Maxwellian distribution function, and 3) that the molecules are solid elastic spheres.

441. Syagayev, V. P. A numerical method for solving the problem of supersonic gas flow around conical bodies. ZhVychMMF v. 3, no. 4 742-754

Supersonic flow of an ideal gas around a conical body having one or several planes of symmetry is discussed. The inverse type method of solving the boundary problem based on iterated numerical solutions of the Cauchy problem with successive correction of the given initial data is used. The results are compared with those obtained by other methods and with experimental data.

442. Borisov, V. M. (Moscow). On optimal shape of bodies in supersonic gas flow. ZhVychMMF v. 3, no. 4 788-793

Two variational problems of gas dynamics are considered: constructing optimal contours for flows of a perfect gas with a shock wave and the minimum-drag generatrices of portions behind the nose of bodies of revolution are determined; and the flow of a real gas.

443. Mikheyev, A. S. Supersonic flow around blunted bodies of revolution.

1964
VoLUMMe As
no. 1
108-113

An adiabatic equilibrium supersonic steady gas flow (of given thermodynamic properties) past a blunted body of revolution with a corner point on its contour is investigated, using a simplifying modification of A. A. Dorodnitsyn's method of integral relations.

GROUP A AEROMECHANICS OF HIGH-SPEED FLOWS

A-3 Testing and Research Facilities
Wind Tunnels
Shock Tubes
Nozzles and Diffusors
Other Testing Facilities
Simulation and Modelling Facilities
Re-Entry Testing Equipment

444. Zemskiy, O. M. (Moscow). Supersonic wind tunnels. — 1940 VoeVorA Rep. No. 60

445. Nedelescu, Ion An open-type supersonic wind tunnel in continuous operation — 1959 StudCeMeAp v. 10, no. 1 287-301

The description and flow parameters of a supersonic wind tunnel at the Traian Vuia Institute of Applied Mechanics are given and its test results are discussed. The possibility of construction of a larger tunnel is examined.

446. Gusev, V. N. A study of flow in a discharge device. — 1961 InZh v. 1, no. 3 161-165

A mathematical investigation of the shock-wave propagation in an electric-discharge device is presented by using a piston analog. The working substance is a perfect gas, and there are no physical or chemical transformations during the motion. A formula for the velocity of wave propagation is derived. Waves with velocities over 10 km/sec can be obtained in the device discussed here.

447. Antonov, A. M., and M. M. Sidlyar. Some approximate solutions of problems of hypersonic flow about slender bodies — PMe v. 7, no. 6 649-656

A theoretical study by the method of successive approximation of bodies at $M \leq 20$ is based on general equations of conservation of mass, momentum, and energy, and continuity of the tangential component of velocity. Numerical data are given on pressures in the flow about a wedge at $M = 17, 18, 19, 20$, and 21.

448. Jungowski, V. M. Methods for calculating stagnation temperature in a hypersonic gun tunnel. — 1962 ~~Arch~~ MeSt v. 14, no. 3-4 491-5-3

An analysis of phenomena in a gun tunnel is presented, along with a description of the method derived by Cox and Winter (AGARD Report 139). A sketch of the apparatus is given together with a time-versus-distance diagram, and an operational description is presented. It is stated that gas friction and heat transfer have little effect on piston motion but quite a distinct effect on stagnation temperature through the attenuation of the primary shock wave and a decrease in gas entropy. The effect of piston weight on the strength of the shock wave is outlined.

449. Lashkov, A. I., and Nikol'skiy, A. A. Shock-wave starting of a supersonic diffuser. — InZh v. 2, no. 1 11-16

A method which uses nonstationary flow phenomena for the starting process of a supersonic diffuser has been developed. The diffusers were tested at M = 2.905 and M = 2.9 and results are shown in spark photographs.

450. Popov, N. N. The problem of imparting high flight velocities to bodies. — VeMoU MMe no. 4 69-74

A numerical solution of the classical Lagrange problem (determining the motion of a piston in a cylinder open on one end and closed on the other end, the space between the piston and the closed end being filled by an ideal gas) is presented. This problem is then applied in the case of one-dimensional motion in a cylinder with the electric and magnetic fields perpendicular to each other and to the velocity vector; the solution is obtained by successive approximations.

451. Krayko, A. N., I. N. Naumova, and Yu. D. Shmyglevskiy. Designing optimum-shape bodies in supersonic flow.

1964
~~PMM~~
v. 28, no. 1
179-182

The design of the shape of the supersonic position of nozzles with maximum thrust is discussed.

GROUP B AEROTHERMODYNAMICS OF HIGH-SPEED FLOWS

B-1 Aerothermophysics
Mass and Heat Transfer
Temperature Distribution
Thermal Radiation Effects
Ionization
Dissociation

		1946
452.	Kalikhman, L. Ye. (Moscow). Heat transfer in the boundary layer. Translation: NACA Tech. Mem. No. 1229 (1949)	PMMe v. 10, no. 4 449-474
		1957
453.	Prokof'yev, V. A. . Influence of radiation on the propagation of small disturbances in viscous heat conducting fluids (hydrodynamic theory). An attempt is made to analyze the radiation problem with an accurate evaluation of the transfer of radiation. Heat radiation and the absorption of radiation energy are taken into account.	IzAN OTN no. 7 94-102
454.	Sidorov, E. A. (All-Union Institute of Heat Technology, Moscow). An approximate solution is derived for the case of nonstationary convection heat transfer.	IzAN OTN no. 9 116-117
455.	Kim, Ye. I. (Kharkov). Concerning one problem of the heat exchange of a system of bodies. A study of the heat-exchange problem of a system of bodies in thermal contact is reported for the case of continuously varying temperature and heat flow in the neighborhood of the contact boundary.	PMMe v. 21, no. 5 624-633
456.	Glikman, V. F. On the problem of nonstationary heat transfer through a plate. Presents an expression for the specific thermal flux through two surfaces of the plate. Values are given for the relative departure of the thermal flux from its stationary value. (Refer to Sov. Phys., Dec. 1957, 2593-2595.)	ZhETeF v. 27, no. 12 2794-2796

457. Grigor'yev, B. A. Some problems of heating an infinite plate by unsteady flows. | 1958 IzAN OTN no. 1 86-94

Unsteady, pulsed radiating flows, whose density at the irradiated surface is expressed by the product of a power and an exponential function (both of time), from the beginning of irradiation, are discussed.

458. Tirskiy, G. A. (Moscow). Nonstationary heat transfer through a system of disks rotating in a viscous fluid. | IzAN OTN no. 7 106-107

A generalization of the problem of nonstationary heat transfer is presented for a system of disks rotating in a viscous liquid.

459. Grigoryan, S. S. On heating and melting of a solid by friction. | PMMe v. 22, no. 5 577-587

The formulation and solution of two problems of heating of solids by friction are presented. The first problem is that of friction between two solids; the second is the flow of a viscous, incompressible fluid past a solid body.

460. Sidorov, E. A. (All-Union Institute of Heat Technology, Moscow). Calculation of effects of a nonstationary regime on convective heat exchange. | Teploenergetika no. 4 79-80

The development and application of approximate methods of calculating the effect of a nonstationary regime on convective heat exchange are presented.

461. Zaydel', R. M., O. S. Ryzhov, and Ye. I. Andryankin (Institute of Chemical Physics, Moscow). Propagation of nearly spherical heat waves. — 1959 DAN SSSR v. 124, no. 57-59

The propagation of heat waves of nearly spherical shape is calculated. The determination of the eigenvalue spectrum and the corresponding eigenfunctions is explained.

462. Fayzullov, F. S., N. N. Sobolev, and Ye. M. Kudryavtsev (Physics Institute, AN SSSR). Temperature of nitrogen and air behind a shock wave. — DAN SSSR v. 127, no. 3 541-544

The experimental results on the temperature of air and nitrogen behind a shock wave, obtained by using the method of conversion of spectral lines with photoelectric recording, are evaluated.

463. Kogan, M. N. (Moscow). High conductivity flows.

Certain characteristic types of flow occurring in the case of high heat conductivity are studied. The process for solving the case of an arbitrary body is briefly indicated, and it is pointed out that in the case of supersonic flow, the turbulence occurs upstream of the body. — DAN SSSR v. 128, no. 3 488-490

464. Tirskiy, G. A. (Moscow). Heating of a heat-conducting wall behind a moving compression shock. — DAN SSSR v. 128, no. 6 1140-1143

An exact solution of the problem of heating of a flat wall behind a plane shock wave travelling through a gas at rest at constant speed parallel to the wall boundary is obtained.

465. Zarubin, V. S. A problem of unsteady heat conductivity. — IzAN EnAvtT no. 2 38-44

The unsteady heat transfer taking place in the casing of a liquid-cooled liquid-fuel reaction engine during transient regimes is discussed. It is assumed that the inner and outer walls of the engine casing are thermally connected by convective heat transfer by means of the liquid coolant whose temperature is time dependent, and that heat flux is proportional to the temperature of a given point at a given time.

466. Sidorov, E. A. (Moscow). A generalization of Gretz's solution to cover the case of radiative heat transfer. — IzAN EnAvtT no. 6 183-185

A generalization of Gretz's solution for convective heat transfer in laminar fluids to cover the case of radiative heat transfer is presented.

467. Sidorov, E. A. (Moscow). The interaction of convection and radiation in an absorbing medium. — IzAN MeMa no. 5 134-136

The further development of previously obtained results on the interaction between heat convection and radiation in absorbing media is presented. The study covers the case of a two-dimensional steady motion of an incompressible fluid in the neighborhood of a nonisothermal surface.

468. Cherpakov, P. V. (Voronezh State University). Periodic solutions of heat transfer equations. — IzVUZ, M no. 2 247-251

Periodic solutions of the equations of heat transfer in finite and infinite regions characterizing the propagation of heat waves are obtained.

469. Merkulov, V. I. (Kiev). Heat transfer in a plane stationary flow of viscous fluid.

PMMa
v. 23, no. 3
581-582

Equations of steady heat transfer in a stationary flow of viscous liquid are derived. The assumptions of constant heat transfer coefficients and of the known solution of the velocity field problem are introduced.

1960

470. Kaplan, S. A., and I. A. Klimishin. Some notes on shock wave radiation.

As Zh
v. 37, no. 2
281-283

The heating of a gas before the front of a shock wave by the radiation emitted by it is discussed. Formulas for calculating the width of the heated zone and its temperature field are given.

471. Nikitin, Ye. Ye. (Institute of Chemical Physics, Academy of Sciences USSR). A mechanism of intermolecular energy exchange during dissociation of a diatomic gas.

DAN SSSR
v. 132, no. 2
395-398

A mechanism for intermolecular energy exchange in the presence of diatomic gas dissociation is discussed.

472. Motulevich, V. P. (Power Engineering Institute, Moscow). Heat exchange at the stagnation point of blunt bodies in supersonic gas flow.

EnI AN SSSR
16-22

A relatively simple method for solving the problem of heat exchange at the stagnation point of blunt bodies in supersonic gas flow is proposed. The method is based on the process occurring in the central stream of the supersonic flow in an inviscid fluid.

473. Kuznetsov, N. M. (Institute of Chemical Physics, Academy of Sciences USSR). — InFZh v. 3, no. 9 17-24

Problems of temperature distribution and concentration of the components of dissociating air in the nonequilibrium region behind a steep shock front are discussed.

474. Mikhaylov, V. V. (Moscow State University). An analytical presentation of thermodynamic functions of dissociated air. — InSb v. 28 36-43

Relatively simple and accurate expressions are given for thermodynamic functions of dissociated air, disregarding processes of additional excitement of the degree of freedom of the particles. It is assumed that progressive energy levels do not depend on inner levels.

475. Kvashnina, S. S., and V. P. Korobeynikov. Solution of some problems of air motion, with dissociation and ionization accounted for. — IzAN MeMa no. 2 34-44

Approximate gas-dynamics formulas are presented for air in the temperature range from 1000 to 20,000° K.

476. Volodina, M. V., Yu. A. Dem'yanov, S. S. Kellin and N. V. Chereshneva. Wall surface temperatures behind a shock wave. — IzAN MeMa no. 6 112-116

A theoretical and experimental investigation of the wall surface temperatures behind a shock wave moving at constant speed is reported.

477. Povitskiy, A. S. Equilibrium temperature of slender bodies in supersonic flow. — IzVUZ AvT no. 1 35-42

The corrections which must be introduced in the coefficients of heat transfer of a flat plate when those coefficients are applied to slender wedges, thin airfoils, slender cones, and slender bodies of revolution moving at high supersonic speeds are discussed.

478. Figurovskiy, V. I. The calculation of the heating of two-layer plates. IzVUZ, AvT no. 2 99-104

The heating of a two-layer plate, one layer of which has low heat conductivity (thermal insulation) and the other is metal, is analyzed under the assumptions that the temperature of the insulation layer is that of the surrounding air and that there is no heat transfer from the free surface of the metal layer.

479. Yarkho, A. A. (Khar'kov). Heat transfer in the neighborhood of the blunt leading edge of a cylindrical wing on slipping. IzVUZ, AvT no. 3 22-27

The solution obtained previously for the problem of heat transfer in the neighborhood of the forward critical point in a plane flow of gas is generalized. The case of steady flow of gas around an infinite cylindrical wing is studied. The assumption of a laminar flow in the boundary layer and of a constant Prandtl number and specific heat is introduced.

480. Alimov, R. Z. (Kazan' Aviation Institute). The influence of diffusion on heat transfer of gases in a boundary layer. IzVUZ F no. 3 97-102

An approximate method is presented for calculating the influence of diffusion on heat transfer of the gas in the boundary layer, based on criterional equations.

481. Petukhov, B. S., and V. V. Kirillov. Heat transfer in a turbulent compressible gas flow in a tube at numbers up to 4.0. — Teploenergetika v. 7, no. 5 64-72

Local heat transfer in a compressible gas flow in a tube with Mach numbers from 0.5 to 4.0, Reynolds numbers from $40 \cdot 10^3$ to $900 \cdot 10^3$, and relative tunnel lengths on heat transfer are determined, and generalized relations for the calculation of heat transfer are presented.

482. Stratonovich, R. L. Fluctuation thermodynamics of nonequilibrium processes. — ZhETF v. 39, no. 6 1647-1659

Equations of the theory of equilibrium fluctuations and of nonequilibrium thermodynamics were derived by establishing a relationship between the fluctuations in two-dimensional distribution and the one-dimensional distribution of a nonequilibrium process. It is shown that the residual correlations and the ergodicity of the system are determined by the behavior of its thermodynamic fluctuations. The Onsager relations are generalized to the case of nonlinear nonequilibrium processes.

483. Nevzglyadov, V. G. Thermodynamics of turbulent systems. — ZhETF v. 39, no. 6 1727-1733

Some consequences of the second law of thermodynamics for single-component turbulent systems are discussed. It is shown that the law must be generalized in order to be applicable to such systems, and this is done by means of the concept of "turbulent-thermal entropy."

484. Loytsyanskiy, L. G. Heat transfer in turbulent motion. — PMMe v. 24, no. 4 637-646

Literature on the theory of heat transfer in turbulent motion is reviewed briefly. The hypothesis of localization is generalized for the case of interactions between the polar and molecular flow past bodies, and von Karman's theory is extended to high Prandtl numbers.

485. Dem'yanov, Yu. A. (Moscow). The boundary layer on a plate of a time-variable surface temperature. PMMe v. 24, no. 4 647-650

A method is developed for calculating the temperature field in the boundary layer of a semi-infinite plate in a uniform flow moving with a velocity V_∞. The onset of heating in the plate is governed by a time-dependent temperature function $T_w(t)$, where T_w is the wall temperature.

486. Kostandian, B. A. (Moscow). On the stability of the solution of the nonlinear heat conduction equation. PMMe v. 24. no. 6 1112-1122

The stability of solutions of the nonlinear heat conduction equation is analyzed. Sufficient conditions of asymptotic stability are obtained by making use of certain approaches in Lyapunov's second method.

487. Nemchinov, I. V. (Moscow). Problems of heat transfer by radiation. ZhPMeTF no. 1 36-57

The equations of radiative heating and cooling by radiation, and equations of motion are analyzed. Self-similar solutions are obtained for the case when the radiation path is a power function of the temperature, and the radiation flux depends on time.

488. Klimov, A. M. Flow of gas with high thermal conductivity near the stagnation point of a blunt body. | ZhPMeTF no. 1 138-141

Heat transfer in ionized and nonionized gases near the stagnation point at arbitrary Prandtl numbers is analysed.

489. Lapin, Yu. V. Friction and heat exchange in a compressible turbulent boundary layer on a plate with the injection of fluid. | ZhTF v. 30, no. 8 984-993

The above mentioned friction and heat exchange analyses are based on boundary-layer equations for a two-component gas mixture under the assumptions that the rate of the inert-gas injection is low, the specific heat is constant, and the Prandtl and Schmidt numbers are each equal to unity. The effect of the physical properties of the injected fluid on the friction and of the injection itself on the distortion of the velocity profile in the boundary layer are discussed.

490. Lapin, Yu. V. Friction and heat exchange in a compressible turbulent boundary layer with injection of a chemically reactive fluid. | ZhTF v. 30, no. 10 1227-1237

The friction and heat exchange in the presence of chemical reactions caused by injection of a fluid into a compressible turbulent boundary layer on a porous plate are investigated under the assumptions that the rate of the chemical reaction is infinitely faster than that of diffusion, and that the Prandtl and Lewis numbers are each equal to unity.

1961

491. Motulevich, V. P. and G. P. Malyshev (Moscow Power Engineering Institute). The effect of dissociation on heat exchange and friction of a plate in an air flow. | EnI AN SSSR 104-113

The calculation of friction and heat exchange of a plate in air flow is examined under two extreme conditions: "frozen" and "equivalent." The equations are based on the real dependence of all calculated parameters on both temperature and pressure in the "equivalent" case, and only on temperature in the "frozen" case.

492. Kutateladze, S. S., and A. I. Leont'yev. Drag and heat-transfer laws in a turbulent boundary layer of a compressible gas and a method for calculating friction and heat transfer. — InFZh v. 4, no. 6 33-41

A method based on limit laws of friction and heat transfer is proposed for calculating these parameters in a turbulent boundary layer of a compressible gas. The theoretical laws of resistance and heat transfer obtained here permit to simplifying the method for solving the integral relationships of the boundary layer in a compressible gas flow with longitudinal velocity and temperature gradients in regions not close to the separation point.

493. Devoyno, A. N. Basic heat-transfer regularity patterns in a rarefied gas due to natural convection. — InFZh v. 4, no. 6 70-77

The problem of heat transfer between a vertical plate and a rarefied gas in the viscous and transient states (corresponding to continuous and slip flow respectively) is discussed. The theoretical solution of the problem is compared with the author's experimental data for a range of pressures from atmospheric to 0.01 mm Hg.

494. Kudryashev, L. I., and A. A. Smirnov (Kuybyshev Aviation Institute). Heat transfer in fluid flow around a cylindrical body. — InFZh v. 4, no. 10 21-29

Unsteady isothermal heat transfer between a cylinder and the flow of an incompressible fluid is studied, and formulas for calculating the heat transfer coefficient are derived on the basis of a semiempirical theory of turbulence.

495. Motulevich, V. P. Heat and mass transfer at the stagnation point of a blunt body. InFZh no. 11 10-18

A theoretical analysis is presented of the heat and mass transfer at the stagnation point of blunt bodies in a multicomponent gas flow with the chemical reactions occurring between the gas and the material taken into account. The relation of ignition and attenuation processes to other parameters is analyzed. For purposes of simplification, the analysis is reduced to that of a homogeneous body with only one irreversible reaction taking place. The analysis indicates that 1) both ignition and attenuation temperature depend on the chemical reaction characteristics of the reacting substances, the flow rate, the gas density, and the dimensions and shape of the body; 2) mass transfer and surface temperature increase with rise in gas-flow temperature for reactions of all types; and 3) higher gas density results in increased mass transfer, as does increased modulus of the heat of the reaction in the case of endothermic reactions.

496. Brovman, M. Ya., and Ye. V. Surin. Heat conduction calculations. InFZh v. 4, no. 12 75-82

An approximate method is proposed for solving heat conduction problems with various boundary conditions. The solution is expressed as a polynomial series. In an illustration of this method, in which heat conduction is considered in the cooling of a plate, the error of the results did not exceed 3 to 4%.

497. Shishkov, Ye. V. Temperature measurements in the boundary layer. — I Khim Ma. Sb. 78-91

Results are presented of an experimental study of the distribution of local values of equilibrium temperatures and pressures on the surface of a thermally nonconductive cylinder in sub- and supersonic flows. Data obtained are compared with calculated data, and some specific conclusions are drawn concerning the work of a thermocouple in a transverse flow.

498. Neyland, V. Ya., and G. I. Taganov. Heat transfer to a body in the vicinity of the frontal separation zone in a hypersonic flow. — InZh v. 1, no. 3 151-153

The maximum heat flow is evaluated in the vicinity of the boundary of the frontal separation zone, under laminar flow conditions. The influence of dissociation on heat flow at certain angles of the conical shock wave is determined.

499. Golubev, V. A. Parameters of turbulent jets at a very high temperature. — InZh v. 1, no. 4 51-58

Plane parallel jet flow of a compressible gas is analysed on the basis of Prandtl's theory of free turbulence, under the assumption that the length of the mixing zone for heat transfer is twice that for transfer of momentum. Calculations are made for a jet initially heated to temperatures of 20,000 and 5000°K. The results obtained and those based on Taylor's theory of turbulence were found to be qualitatively comparable.

500. Naziyev, Ya. M. The temperature distribution in an infinite hollow cylinder. — IzAN EnAvt no. 4 60-63

The heat-conductivity problem is considered in the case of an infinite hollow cylinder

thermally insulated on the outside and with an inner surface heated by a heat flow which varies exponentially. Applying the Laplace transformation to heat-conductivity equations with corresponding boundary conditions, a transform pair of the solution of the equations is derived, establishing the distribution of the temperature in the cylinder. Exact and approximate solutions are also presented for the case when the temperature on the outside surface of an infinite hollow cylinder is maintained constant and the inside surface is heated by a heat flow varying exponentially.

501. Rumynskiy, A. N. Heat transfer near the stagnation point. IzAN MeMa no. 1 96-101

The effect of radiation on convective heat transfer near the forward stagnation point of an axisymmetric blunt body in a hypersonic stream of radiating and absorbing gas is discussed.

502. Shakhnov, I. F. Disturbance of a supersonic flow induced by discrete or continuously distributed heat sources. IzAN MeMa no. 5 16-21

Expressions are given for the distribution of disturbances in an originally undisturbed flow of ideal gas. It is demonstrated that at a given distribution of heat sources in the flow, condensation or rarefaction waves may appear; on the other hand, it is possible to reduce some shock waves in an adiabatic flow over bodies by introducing an adequate heat supply.

503. Stulov, V. P. (Moscow). Heat transfer in a laminar boundary layer. IzAN MeMa no. 6 11-14

Calculations of the heat transfer in a boundary layer on a plane plate are presented which take account of chemical nonequilibrium. The results indicate that nonequilibrium in a gas particle does not affect the rate of heat flow significantly.

504. Shakhnov, I. F. The method of small disturbances applied to nonadiabatic supersonic flow. — IzAN MeMa no. 6 37-41

Flow parameters are established and discussed for a gas flowing at supersonic velocity over a flat plate at zero angle of incidence. A rectangular zone of heat transmission adjoins the plate. Basic parameters determining the flow inside and outside the heating zone are given.

505. Suksov, I. I. Determination of the thermal characteristics of a two-dimensional laminar boundary layer in a compressible gas without a longitudinal pressure gradient in the region of the stagnation point. — IzVUZ, AvT no. 1 27-37

Simple approximate solutions are presented which give good results in determining the coefficients of friction, recovery, and heat transfer for a plane plate and for the stagnation-point region. Analogous solutions can be obtained when the effect of high aerodynamic heating is taken into account. The method can be extended to bodies of revolution.

506. Bulygina, Ye. V., M. B. Polyakov, and Ya. S. Shcherbak. Thin airfoil with the minimum mean heat-emission coefficient for a given lift. — IzVUZ, AvT no. 2 17-25

A theoretical solution is derived for the problem of determining an airfoil shape which would provide the least mean heat emission coefficient for a given lift. It is assumed that the airfoil is thin, that both the top and the bottom surfaces are heat insulated, and that the boundary layer is either fully laminar or turbulent.

507. Kudryashev, L. I., and V. K. Lyakov. The influence of longitudinal nonisothermicity on heat-transfer coefficient. — IzVUZ, AvT no. 4 104-110

The problem of finding the heat-transfer coefficient in the case of a turbulent flow in hydraulically smooth conduits was reduced to determining a system of differential equations of the boundary sublayer. The heat-transfer coefficient was computed theoretically for large longitudinal nonisothermicity, and the functional form of the correction-factor equation is found on the basis of a turbulent heat-transfer model. It is shown experimentally that if physical parameters are determined at the mean temperature of the flow, then the experimental data are best generalized in the form of an equation of the dimensionless temperature in functions of Reynolds and Prandtl numbers and the quotient of the length and diameter of the tube. The generalizati[illegible] of experimental data according to the existing formula, with the correction facto[illegible] taken into account, requires the int[illegible] [illegible]action of the actual mean temperature gradient and complicates the procedure. A simple method for practical evaluation of the influence of longitudinal nonisothermicity is given.

508. Fedorov, I. G., V. K. Shchulin, G. A. Mukhachev, and N. S. Idiatulin. Heat transfer and hydraulic resistance in laminar conduits consisting of two 0.5-mm steel sheets, maintained at a distance of 2.5 mm by projections 6.5 mm in diameter produced by stamping with spherical dies. Thus, a channeled or checkered pattern was formed. Four different samples were tested in 18 to 20 regimes determined by air consumption in the range of Reynolds numbers from 500 to 18,000. The results obtained are presented graphically with the Nusselt number and hydraulic resistance as functions of the Reynolds number. — IzVUZ, AvT no. 4 120-127

509. Gribkova, S. I., and L. S. Shtemenko. (Institute of Heat and Mass Transfer, Academy of Sciences BSSR). An experimental investigation of slip and temperature jump in a flow of rarified air around a solid wall. — Konf. Tp Mas

Translation: by ATD, Library of Congress, Report No. T-63-64

The following papers were presented at the Conference of Heat and Mass Exchange sponsored by the Belorussian Academy of Education USSR, the Academy of Construction and Architecture USSR, and the Institute of Mechanics (Academy of Sciences USSR). This conference was held in Minsk in June 1961.

510. Kudryashev, L. I., and V. A. Dzerul'skiy (Kuybyshev Aviation Institute). Demonstrating the existence of heat regularity in a boundary layer with internal problem conditions. — Konf. Tp Mas Minsk. 1961

Translation: by ATD, Library of Congress, Report No. T-63-70

Printed in rototype at the Institute of Scientific-Technical Information and Propaganda. Council of the National Economy BSSR.

511. Perel'man, T. S. (Power Institute, Academy of Sciences BSSR, Minsk). Heat exchange in the laminar boundary layer during flows around a plate with internal sources. — Konf. Tp Mas Minsk. 1961

Translation: by ATD, Library of Congress Report No. T-63-74

512. Sovershennyy, V. D., and G. A. Tirskiy. (Central Institute of Aviation Motors, Moscow). Sublimation of a solid in the vicinity of a critical point in plane and axisymmetric gas flows. — Konf. Tp Mas Minsk. 1961

Translation: by ATD, Library of Congress, Report No. T-63-68

513. Popov, N. A., and V. I. Rakhovskiy (All-Union Electrical Institute). The problem of cermet depletion by highly volatile components during heating in a vacuum. — Konf. Tp Mas Minsk. 1961

Translation: by ATD, Library of Congress, Report No. T-63-72

514. Tsoy, P. V. (Dushanbe Polytechnical Institute). Analytical solutions of a system of heat and mass exchange equations for a semifinite medium under various boundary conditions. — 1961 Konf. Tp Mas Minsk. 1961

Translation: by ATD, Library of Congress, Report No. T-63-65.

515. Vulis, L. A., T. P. Leont'yeva, I. B. Palatnik, Z. B. Sakipov, and B. P. Ustimenko. (Power Institute, Academy of Sciences, KazSSR). Transfer processes in a free (jet) turbulent boundary layer. — Konf. Tp Mas Minsk. 1961

Translattion: by ATD, Library of Congress, Report No. T-63-73.

516. Zhukauskas, A. A., V. I. Makariavichus, and A. A. Shlanchyauskas (Institute of Power and Electrical Engineering, Kaunas). The problem of the emission of heat in smooth pipe bundles in crossflow liquids. — Konf. Tp Mas Minsk. 1961

Translation: by ATD, Library of Congress, Report No. T-63-69

517. Lapin, Yu. V. Heat transfer in a turbulent boundary layer. — LPoI GiTr no. 217 27-36

Heat transfer in a turbulent boundary layer in a supersonic gas flow with a moderate

pressure gradient and nonuniform temperature distribution at the wall is determined by Karman's semiempirical theory. The temperature range investigated is that in which the Prandtl number and specific heat capacity may be considered as constants independent of temperature. Solution of the momentum integral equation and calculation of the heat transfer on the basis of a Reynolds analogy are presented. A numerical example of calculating the heat transfer and the skin friction on a wing airfoil in a supersonic flow (flight altitude 20 km at M_∞=6; T_w=700°K) is given.

518. Tirskiy, G. A. (Moscow). Conditions on the surface of a strong discontinuity in multicomponent mixtures. PMMe v. 25, no. 2 196-208

An analysis of the conditions on the surface of a strong discontinuity in multicomponent mixtures is presented. Relations are derived for viscous heat conducting multicomponent mixtures, taking into account the effect of thermal diffusion. An approximation of the boundary-layer theory is used to derive relations valid on the surface of discontinuity (density, pressure, particle velocity, temperature, and composition). Flow past a porous flat plate, allowing for the evaporation of the liquid film, as well as the case of a uniform gas flow past a sublimating wall are discussed as examples.

519. Pashchenko, N. T. Some aerothermodynamic problems associated with a free-molecule flow pattern. PMMe v. 25, no. 6 1132-1138

In investigating the heat supply in rarefied gases the temperature of a slender body in a translatory motion accompanied by small transient motions (for example, oscillation) in cases of convective and radiative heat exchange is determined as a function of time, local angle of attack, velocity, surface characteristics, and thermodynamic parameters of the medium at high altitudes.

520. Drushinin, S. A. Calculation of internal heat exchange during porous cooling. — Teploenergetika v. 8, no. 9 73-77

A method is presented for experimental study of the internal heat exchange in porous metals heated by high-frequency currents. Tests performed on two air cooled stainless steel specimens with 30% and 50% porosity are described.

521. Bashkin, V. A., and Ye. Ye. Solodkin. On determining the heat transfer coefficient. — ZhPMeMF no. 3 16-24

Convective heat transfer between body and gas in high hypersonic flows (up to M=20) with boundary layer temperatures over 20000K is discussed.

The specific heat flux with a zero pressure gradient in flow direction in cases of a constant and longitudinally variable surface temperature is determined, taking into account the dependence of thermodynamic functions and transfer coefficients on the temperature. The case when both the pressure gradient and the temperature vary along the body surface is also briefly discussed. The application of results obtained to a turbulent boundary layer and to determining the heat transfer coefficients from experimental data is explained.

522. Marenov, A. E. (Institute of Mechanics, Academy of Sciences USSR). An investigation of the heat exchange in supersonic gas streams flowing through a probe with a laminar boundary layer. — ZhTF v. 31, no. 9 1001-1011

The local heat transfer coefficients in a supersonic flow of air through a cylindrical tube of constant cross section and a laminar boundary layer were determined experimentally. It was found that the gas flow cannot be stabilized over the given

tube length, with the result that the heat transfer coefficients are variable, decreasing from the beginning of the tube toward its end to the critical value of the parameter Re_x, referred to the length of the tube.

523. Lapin, Yu. V. (Leningrad Polytechnical Institute). Mass-heat transfer in turbulent, compressible flow with the addition of foreign matter. — ZhTF v. 31, no. 11 1395-1406

A tentative estimate of the effect of the presence of a laminar flow along a surface $Pr \neq Sc \neq 1$. is obtained. The methods described were based on the assumption that the mean values of the numbers Pr and Sc are constant throughout the laminar sublayer. Calculations are presented for cases in which air and helium are used as coolants. The general conclusion is that when the coolant is a light gas, the amount by which the Prandtl and Schmidt numbers differ from unity must be taken into account.

1962

524. Kobanskiy, P. N. Forced flow heat transfer from a heat exchange surface with a resonance system in the wall. — AKZh v. 7 313-319

The effect of secondary streams generated by a resonance system on heat exchange in forced convection is analyzed. Equations are obtained for computing the heat transfer coefficient under these conditions. The results of the theoretical calculations and experimental observations were compared and showed satisfactory agreement. On the basis of this comparison, the physical effects observed on surfaces with resonance systems in the walls are given a more accurate description. Limits are found for the maximum possible intensification of the heat transfer process by the given method.

525. Madejski, J. The thermal laminar boundary layer at high velocities. Arch MeST v. 14, no. 6 865-873

Heat transfer in a high-velocity fluid flow over a flat plate with constant temperature is analyzed. The laminar boundary layer equations are integrated to yield two equations which can be used to determine the thickness of both the thermal and the hydrodynamic boundary layers. These equations can also be used in case of variable wall temperatures (insulated surfaces).

526. Bronskiy, L. N., and O. N. Kastelin (Power Engineering Institute, Moscow). Heat transfer on rough and smooth bodies in supersonic flow. InFZh v. 5, no. 4 135-140

Test results are presented on investigation of heat transfer in axisymmetrical plane, spherical, and ellipsoidal models with smooth and rough surfaces in supersonic (up to M=2.77) high-temperature (up to 420°C) jets.

527. Kastelin, O. N., and L. N. Bronskiy (Power Engineering Institute, Moscow). Heating of the front part of blunt bodies in supersonic flow. EnI AN SSSR 233-238

Two methods were used to investigate the heat transfer from a gas to blunt axisymmetrical bodies in the vicinity of the stagnation point: the exponential method and the method of surface points.

528. Polyakov, Yu. A. A thin-film transducer for studying heat transfer in dissociated gas flow. EnI AN SSSR 251-260

A resistance thermometer consisting of a

2mm wide Pt film 0.1 μ thick deposited on the spherical end of a glass tube (11 mm in diameter) was prepared by sintering, after coating the tube with a paste containing chloroplatinic acid. The film was connected to Pt wires inside the tube and mounted at the stagnation point of an axisymmetric blunt body. Experiments at M = 4 to 12 were conducted in a shock tube 50 mm in diameter and 4.5 m long to study the unsteady heat transfer between the model and a shock wave propagating in air.

529. Yaryshev, N. A. (Institute of Precision Mechanics and Optics, Leningrad). Criteria of irregularity of temperature distribution and coefficients of the shapes of bodies in a regular second-order regime. — InFZh v. 5, no. 4 135-140

The results of a study of nonuniformity of the temperature distribution and determination of the coefficients of body shape in the case of homogeneous isotropic bodies in a regular, second-order regime are presented. This regime represents heat exchange between a body, or a system of bodies, and the surrounding medium whose temperature varies with time at a constant rate.

530. Koshmarov, Yu. A. Turbulent flow of an incompressible fluid in the gap between rotating coaxial cylinders. — InFZh v. 5, no. 5 5-14

A theoretical study was made of the hydrodynamics and heat transfer of a perfectly turbulent flow in the annular channel (gap) formed by two coaxial cylinders rotating with respect to one another. The gap is assumed to be small compared with the radii of the cylinders. Both the axial and tangential velocity profiles are calculated and the turbulent viscosity coefficient

established from the results. The thickness of the laminar sublayers is determined from the value of the total tangential stress on the wall. Formulas obtained for the coefficients of axial friction are shown to be in good agreement with experimental data. The coefficient of heat transfer is determined from the calculated temperature profile in the turbulent part of the flow.

531. Shul'man, Z. P. (Power Engineering Institute, Academy of Sciences, BSSR). Laminar boundary layer with heat and mass transfer. — InFZh v. 5, no. 5 102-104

An empirical formula is given for calculating heat transfer in a slightly curved body of arbitrary shape when in a flow of an incompressible binary gas mixture, mass transfer of various substances takes place through the walls into the laminar boundary layer.

532. Chaplina, A. I. (Power Engineering Institute, Academy of Sciences BSSR, Minsk). An experimental investigation of heat exchange of a longitudinally streamlined plate. — InFZh v. 5, no. 7 34-38

Local heat transfer between a plate and a longitudinally forced turbulent air flow was investigated experimentally. An expression was derived which shows that the ratio of the mean heat transfer coefficient at the end of the plate is independent of the stream velocity and that the dependence of the mean heat transfer coefficient upon the stream velocity is analogous to that of the local heat transfer coefficient.

533. Polyak, G. L., and V. N. Adrianov (Moscow Power Engineering Institute). The algebra of radiant exchange flows. — InFZh v. 5, no. 7 70-77

A system of equations was derived for calculating the radiant exchange in arbitrary systems of nonblack bodies. The analysis is based on formulas which express the general properties of the resolving fluxes in radiant exchange.

534. Kosterin, S. I., and Yu. P. Finat'yev (Institute of Mechanics, Academy of Sciences USSR, Moscow). Heat transfer in a turbulent air flow between rotating coaxial cylinders. — InFZh v. 5, no. 8 3-9

Heat transfer from a stationary, electrically heated outer cylinder to a rotating coaxial inner cylinder was measured as a function of the rotation speed and the rate of air flow through the annulus between the cylinders. Equations are derived for calculation of 1) heat transfer between the cylinders, and 2) the transition from pure turbulent flow to a turbulent flow involving strong vortices.

535. Bukhvolstov, A. P., and V. Ya. Frenkel'. Temperature distribution over plates radiating heat in vacuum. — InFZh v. 5, no. 8 78-80

The thermal behavior of circular, rectangular, and square plates with a given constant contour temperature during cooling by heat radiation in vacuum is analyzed mathematically. Expressions are derived which show the interrelationships among the contour temperature, the minimum temperature on the surface, the geometrical parameters of the plate, and the physical characteristics of the plate material.

536. Mironov, V. F. (Power Engineering Institute, Academy of Sciences BSSR; Polytechnical Institute, BSSR). Heat and mass transfer from bodies to a flow of air. — InFZh v. 5, no. 10 9-12

Heat and mass transfer of various bodies (sphere, cone, disk, and cylinder) in a steady turbulent flow and in a pulsating flow have been experimentally investigated in a wind tunnel. Results were obtained in terms of Nusselt criterion relations.

537. Mukhin, V. A., A. S. Sukomel, and V. I. Veluko (Moscow Power Engineering Institute). Heat transfer in supersonic gas flow through a tube with large temperature gradients. — InFZh v. 5, no. 11 3-7

Local heat transfer coefficients and heat fluxes were measured during cooling of air by water in a brass tube. It was shown that the adiabatic wall temperature ratio which varied from 1 to 3.1 did not affect the Nusselt number under the conditions studied. The study was made at the Power Engineering Institute imeni G. M. Krzhizhanovskiy, Academy of Sciences USSR.

538. Danilov, Yu. I., and B. M. Galitseyskiy (Moscow Aviation Institute). Gas motion in a straight duct with friction and heat transfer. — InFZh v. 5, no. 11 8-11

An exact solution was obtained for a gas dynamics equation describing the motion of a gas in a straight duct with simultaneous friction and heat transfer, under the assumptions that the friction coefficient is constant and that the temperatures change linearly along the duct. The study was made at the Moscow Aviation Institute imeni S. Ordzhonikidze.

539. Kosterin, S. I., Yu. A. Koshmarov, and Yu. V. Osipov. Investigation of rarefied-gas flow and heat exchange in a flat supersonic nozzle. InFZh v. 5, no. 4 3-9

Heat exchange and frictional resistance in air are investigated in six nozzles for $\sqrt{Re}/M = 5$ to 50. Results are discussed and shown in graphs.

540. Koshmarov, Yu. A. Heat transfer in a turbulent boundary layer. InZh v. 2, no. 1 41-54

An experimental study of heat transfer in a turbulent boundary layer of a supersonic flow of a compressible gas with negative longitudinal pressure gradients is presented together with a simple method for calculating the heat-transfer coefficient in the turbulent boundary layer of a compressible gas. The results are applicable to heat-transfer calculations in supersonic nozzles.

541. Bronshten, V. A. On ionization and recombination processes in hot air. InZh v. 2, no. 1 163-170

Ionization of air atoms behind very strong shock waves (such as are formed behind meteorites passing through the atmosphere) and recombination are discussed for hydrogen-like and compound atoms and ions. The ionization and recombination coefficients are determined.

542. Kosterin, S. I., Yu. A. Koshmarov, and N. M. Gorskaya. Experimental investigation of heat transfer on a flat plate in a supersonic flow of rarefied gas. InZh v. 2, no. 2 263-269

The temperature and average heat transfer coefficients of a plate are measured in a supersonic flow at a zero angle of attack at $M = 2.6$ to 3.2 and $Re = 20$ to 240.

543. Repik, Ye. U., and V. Ye. Chekalin. Convective heat transfer in supersonic conical nozzles. — InZh v. 2, no. 2 359-364

Heat transfer was studied experimentally in a specially designed apparatus. The tests were conducted at 4 to 5 atm, 695 to 795°K, and a nozzle-outlet velocity of M = 5.

544. Artamonov, K. I., and I. G. Krutikova. Thermoacoustic instability of an inhomogeneous gas flow. — IzAN MeMa no. 3 19-23

Self-excited oscillations in a one-dimensional uniform gas flow with evenly distributed internal heat sources are discussed for the cases of constant and variable temperature gradients. In the first case, the flow is steady; in the second case, self-sustained oscillations occur due to interaction of the pressure and entropy waves.

545. Litvin-Sedoy, M. Z. Limitation of oscillations in aircraft autopilot systems. — IzVUZ, AeT no. 2 39-47

An analytical method is presented for deriving a linear system control law for producing the desired limitation of controlling coordinates when disturbed motions are caused by specific instantaneous initial deviations of variable systems. The above is related to aircraft-autopilot systems, in which a specific restriction of oscillations of disturbed motion and maintenance of asymptotic stability of the motion are required. The method is based on evaluating the maximum value of the solution of a steady linear homogeneous differential equation with constant coefficients at given initial conditions.

546. **Yeh, T'ien-ch'i.** Determining unsteady temperature fields in structures in transient flight regimes with regard to thermal radiation. IzVUZ, AvT no. 2 56-64

The generation of unsteady temperature fields in aircraft structures by kinetic heating at high altitudes and large Mach numbers is discussed, taking account of heat radiation. An approximate finite-difference procedure, convenient for practical calculations, is used. Results of a sample calculation for a steel aircraft in accelerated flight (from M = 2 to M = 5 in 90 sec) at 1500 m altitude are presented.

547. **Yasinskiy, F. G.** Analysis of heat flow through a three-layer plate. IzVUZ, AvT no. 2 95-101

Heat flow through an infinite plate consisting of a metallic sheet with a heat-resistant (for example, ceramic) coating on its outer surface and an insulating coating (for example, fiberglass) on its inner surface was studied without considering heat radiation. The cumbersome formulas obtained can be simplified for given heat capacities of layers.

548. **Dolomanov, Ye. G.** Inversion phenomena in supersonic flows of real gases. IzVUZ, AvT no. 2 124-129

It is shown that impact temperature inversion must occur in compression shocks; incorrect results are possible if this fact is not taken into account in calculating the deceleration temperature behind the pressure shock in real gases.

549. **Kudryashchev, L. I., and I. A. Gusev,** The effect of nonstationary pulsating gas flow on heat-transfer characteristics. IzVUZ, AvT no. 2 152-158

An analytical and experimental study has been conducted on the effect of unsteady pulsating gas flow around a body on heat transfer. The effect of flow velocity and of the amplitude and frequency of pulsation was examined. The used equipment and investigation method are described, and results are discussed in detail.

550. Suksov, I. I. An approximate method for calculation of steady high-temperature gas flow. — IzVUZ, AvT no. 2 159-167

A study has been made of a high-temperature gas flow in the presence of dissociation and ionization. Equations of a steady flow with heat transfer are derived, an approximate grapho-analytical method is developed, and the effect of luminosity is discussed in detail. For evaluation of the combined effect of convective heat transfer, luminosity, and friction, a numerical example of a turbulent isentropic flow is given.

551. Alishaev, M G. (Moscow). Forced convection of a viscous compressible gas near the heat source. — PMMe v. 26, no. 1 187-189

Forced convection in the neighborhood of a heat source placed in a homogeneous flow of a viscous, heat conducting gas is studied. The approximate boundary layer theory is used, and it is shown that the problem can be reduced to the corresponding problem for incompressible fluids by means of the Dorodnitsyn transformation, if the temperature dependence of viscosity is considered in the form given by Chapman-Rubesin, and if the Prandtl number is taken as a constant.

552. Zarubin, V. S. Calculation of temperatures in two-layer metal plates. — Voprosy Mekhaniki, Sb. 127-137

The unsteady heat transfer equation for a wall consisting of two metal plates and an intermediate layer of insulating material is solved by means of Laplace transformations to yield a space-time relationship for the wall temperatures.

553. Petrashhitskiy, G. B., and V. I. Polezhayev. An engineering method for calculating nonstationary processes of heat conductivity in thin multilayer walls. — Teploenergetika v. 9, no. 2 73-76

Derivation of a solution to the one-dimensional heat transfer equation with third-order boundary conditions is obtained. The solution method is illustrated, and results are presented for the case of heat transfer in thin, laminated plates.

554. Fedorov, I. G., N. S. Idiatuffin, V. K. Shchukin, and G. A. Mukhachev (Kazan' Aviation Institute). Heat transfer and hydraulic resistance of slit channels with a checkered distribution of conical indentations. — Teploenergetika v. 9, no. 6 57-60

Experimental investigation of heat-exchange slit channels is presented. Equations are given for the evaluation of heat exchange over the range Re = 750 to 18,000 and for hydraulic resistance over the range Re = 750 to 20,000.

555. Bulyeyev, N. N. A theoretical model mechanism for turbulent transfer in fluid flow. — Teploperedacha 64-97

The proposed three-dimensional heat- and

mass-transfer model is based on the use of nine-component turbulent stress vectors for mass and heat transfer. The velocity profile in a rectangular duct at a given distance from the inlet section, and the velocity and temperature profiles in a tube were determined on the basis of the model.

556. Porvchikov, V. B. Temperature of the leading edge of a plate in aerodynamic heating. — VeMoU MMe no. 1 47-52

The laminar boundary layer in a steady compressible gas flow past a semi-infinite thin plate is discussed and the time dependence of the temperature of the leading edge is analyzed, taking account of heat flow through the leading edge.

557. Rumynskiy, A. M. (Moscow). The effect of diffusion of radiant components on convective heat exchange. — ZhPMeTF no. 2 50-58

Gas-dynamic hypersonic-flow parameters of the boundary layer in the region of the forward stagnation point of an axisymmetrical blunt body are analyzed with regard to diffusion effects, and liberation of heat-radiating gas from the body surface. The energy equation is used to derive formulas for determining the parameters of convective heat transfer in the vicinity of the stagnation point.

558. Kaganov, M. A., and Yu. L. Rozenshtok. On the temperature of bodies in a medium with pulsating heat emission and temperature. — ZhPMeTF no. 3 90-92

The temperature fields in an infinite cylinder and a sphere placed in a medium with harmonically varying temperature and

heat emission are discussed, taking account of fluctuations in their amplitudes and mutual phase shift.

559. Onufriyev, A. T. An approximate study of the problem of flow of a radiating gas about a plate of finite length. ZhPMeTF no. 5 70-74

It is demonstrated, by using a flat plate as an example, that the heat flow to a body in a stream of high-temperature gas depends on the ratio of the radiation period to the dimensions of the body.

560. Vaulin, Ye. P., and N. N. Gvozdkov. On diffusion cooling of a porous plate in a gas-dynamic flow by injection of fluid with physicochemical reactions into the laminar boundary layer. ZhTF v. 32, no. 2 238-247

The process of heat exchange in a porous plate with injected fluid is examined, and the laminar-boundary equations are analyzed, taking into account the physicochemical transformations and diffusion of reaction products and evaporation into the gas flow.

1963

561. Grishin, A. M., and O. M. Todes (Saratov Polytechnical Institute). Thermal explosion in the presence of heat transfer by convection and conduction. DAN SSSR v. 151, no. 2 365-368

A theoretical analysis was made to establish the accuracy and applicability of the formula previously derived by the author as a criterion for thermal explosion on the assumption that heat removal takes place by convection only.

562. Motulevich, V. P. Turbulent heat and mass exchange on a plate with suction or injection of various gases. InFZh v. 6, no. 1 3-13

A theoretical analysis of the effect of suction or injection of various gases through a porous plate in a gas flow on the heat exchange and friction in the turbulent boundary layer is presented.

563. Romanenko, P. N., and V. N. Kharchenko. Effects of transverse mass flow on drag and heat exchange in turbulent compressible gas flow. InFZh v. 6, no. 2 52-57

Experimental data on the effects of injection of various gases (air, helium, carbon dioxide, and freon-12) through a heated porous plate into a turbulent boundary layer of hot air (450 to 550°K) on heat exchange and drag are presented. Potential flow velocity was 25 to 75 m/sec, Reynolds numbers 10^5 to 5×10^5.

564. Motulevich, V. P. The effect of removal or injection of substances through porous walls on heat transfer to blunt bodies. InFZh v. 6, no. 4 9-15

An analysis was made of incompressible fluid flow past the stagnation area of a blunt axisymmetrical body through whose walls a fluid is injected or, by suction, withdrawn from the main stream. A general heat transfer formula in terms of the Gauss function and the ratio of the Nusselt numbers for porous and impermeable walls was derived. It is shown that the formula yields results which are in good agreement with values calculated by Hartnett and Eckert, who used a laborious numerical method. The solution for the injection of a fluid having different physical properties than the main flow showed that fluid injection decreases heat transfer; the effect of injection increases with an increase in

the spacific heat of the injected fluid and with a decrease in its thermal conductivity and density.

565. Usanov, V. V. Possible solutions of thermodynamic equations for viscous gas flow with heat transfer. InFZh v. 6, no. 4 22-26

A system of equations in terms of gas-dynamic influence coefficients describing one-dimensional gas flow with allowance for friction and heat transfer through the wall is considered. Possible methods of solving the equations are discussed. It is shown that in case of intensive heating, the effect of heat transfer on the friction factor must be taken into consideration.

566. Kudryashev, L. I., and V. K. Lyakhov. The dependence of heat transfer coefficient on longitudinal and transverse nonisothermicity in turbulent fluid flow. InFZh v. 6, no. 4 56-60

An analysis based on a two-boundary-layer model was made to derive generalized relationships for turbulent heat transfer, with allowance for transverse and longitudinal variations in physical properties.

567. Chervyakov, S. S. (Institute of Heat and Mass Transfer, Academy of Sciences BSSR). An experimental study of the influence of vibrations on heat and mass transfer of a cylinder and a cone in turbulent air flow. InFZh v. 6, no. 8 10-14

Experimental data were obtained on the influence of vibrations on the heat and mass transfer of a cylinder and a cone under various flow conditions. The procedure and method used in the experiments are the same as those used by Chervyakov

with a sphere (InFZh, no. 6, 1963). The Re number varied from 2.8 X 10^4 to 7.6 X 10^4, the degree of turbulence of the air flow varied from 2.4 to 3.2%, and the temperature 40°C. The frequency of vibration of a test model was varied from 9 to 16.5 cps at an amplitude of 12 mm.

568. Dolinskaya, R. A. Bibliography of heat and mass exchange. InFZh v. 6, no. 9 127-137

This bibliography lists 11 books, including two translations and 250 Soviet journal articles, most of which were published in 1962-1963. The subjects include mathematical methods (29 articles), experimental methods (35 articles), superhigh speed processes (7 articles), thermophysical and thermodynamic properties of materials (15 articles), physics of high-temperature processes and magnetic hydrodynamics (64 articles), processes in nuclear reactors (14 articles), and processes and apparatus (31 articles).

569. Kozlov, L. V. An experimental investigation of surface friction on a plate in supersonic flow with heat exchange. IzAN MeMa no. 2 11-19

The values of local surface-friction coefficients on a plate at zero angle of attack in subsonic and supersonic flows with extensive heat exchange between the plate and flow are experimentally determined. Brief descriptions of the surface-friction transducer and of the testing technique are given. An empirical formula is obtained for calculating the friction coefficient in a turbulent flow over a wide range of Mach and Reynolds numbers and temperatures.

570. Tagirov, R. K. (Moscow). Calculation of heat fluxes in the flow of two different supersonic streams about a step. IzAN MeMa no. 6 55-61

A method is developed for calculating the base enthalpy and base temperature in the flow over a flat or round back-step by two different supersonic streams having different Mach numbers, total pressures, and stagnation enthalpies.

571. Tirskiy, G. A. Heat transfer to cylinder in flow of dissociating air. IzAN Me no. 6 125-130

Formulas are derived for calculating two cases of specific heat fluxes to the leading edge of a swept-back wing (cylinder of infinite length) in a flow of dissociating air: 1) equilibrium dissociation in the boundary layer, and 2) "frozen" flow over ideal catalytic and noncatalytic surfaces. The determination of the flow in the boundary layer in the vicinity of the leading edge of the cylinder, with the recombination of air atoms in the relatively cool boundary layer taken into account, is reduced to the solution of the boundary problem presented by the author in a previous work.

572. Nikitenko, N. I. The numerical solution of a temperature field problem. IzVUZ, AvT no. 1 26-32

The problem of determining the nonstationary temperature field in a moving medium is studied. The problem is reduced to the solution of a heat propagation equation; it is proposed to do this by the method of numerical integration. The method is illustrated by a solution of the problem of the temperature field of a laminar flow in a circular tube. It is shown that the numerical solution results are in good agreement with Nusselt's analytic solution of this problem.

573. Sozin, Yu. A. Heat transfer during pulsed flow of an incompressible fluid. IzVUZ, AvT no. 2 102-110

An analysis was made to derive relationships which can be used in the design of heat exchangers with pulsed flow of incompressible fluid. The effect of the nonlinear relationship between the heat transfer coefficient and sinusoidal flow pulsations was expressed by the formula:

$$\delta\alpha = \frac{\Delta\alpha}{\alpha_1} 100\% = -4(U_o') \%$$

where $\delta\alpha$ is the relative change in the heat transfer coefficient; $\Delta\alpha$, the absolute change in the heat transfer coefficient; α_1, the heat transfer coefficient under steady flow conditions; and U_o', the relative amplitude of flow velocity pulsations. The formula shows that, compared with steady flow, flow pulsations caused a decrease in the average heat transfer coefficient.

574. Sozin, Yu. A. An experimental study of convective heat transfer in pulsed flow of an incompressible fluid. — IzVUZ, AvT no. 3 87-91

A study of pulsed heat transfer has been made in an annulus 276 mm long. Results for steady and pulsed flow are given. It is concluded that the majority of the experimental points for pulsed flow are located below the line calculated for steady flow, so that flow pulsations generally reduce the heat transfer. At low and intermediate pulsation amplitudes, pulsed heat transfer is not more than 4—5% lower than under steady flow conditions; this is within the limit of experimental error. Therefore, pulsed heat transfer can be calculated by conventional methods for steady flow.

575. Shlanchiauskas, A., I. Zhiugzhda, and A. Zhukauskas. Heat exchange in a boundary layer. — Mokslas ir Technika no. 4 34-35

Relationships for calculating heat exchange when the properties of a fluid

are changing were derived by measuring the velocity and temperature fields in the boundary layer over a heated and cooled plate in oil and water jets.

576. Kutateladze, S. S., and A. I. Leont'yev. Protecting bodies by a cooling turbulent boundary layer. — Teplofizika Vys Tm v. 1, no. 2 281-290

The problem of protecting bodies in a high-temperature gas flow by forming a cold boundary layer on them is discussed. The cooling boundary layer is established either by extensive cooling of the front portion of the body, or by making this portion porous (or with slits) with injection of cold gas.

577. Panevin, I. G., and P. P. Kulik. A method for experimental determination of the coefficient of thermal conductivity of a high-temperature gas. — Teplofizika Vys Tm v. 1, no. 3 394-398

An experimental method is presented which is based on the fact that regardless of the conditions in a flow around a blunt body, the stream in a small area around the critical point is always laminar. Since heat transfer transverse to the laminar boundary layer is due only to molecular heat conduction, measurement of the temperature profile in the boundary layer near the critical point and determination of the heat flux at this point yields the value of the coefficients of molecular thermal conductivity in a larger range of temperatures than possible heretofore. The experimental set-up has been described elsewhere (V. B. Tikhonov, Ye. A. Yakovlev, Sb. tr. MAI, A. V. Kvasnikov, ed, Oborongiz 1960). The experimental results agreed within 9% at T = 12,000K and 5% at T = 14,000K with approximate theoretical values calculated by the method of W. Lochte-Holtgreven (Repts. Progr. Phys. v. 21, 312, 1958). It is pointed out that the method is most effective at high pressures. Orig. art. has: 7 figures and 3 formulas.

578. Kutateladze, S. S., and A. I. Leont'yev. The effect of gas dissociation on friction and heat exchange in a turbulent boundary layer. — Teplofizika Vys Tm v. 1, no. 3 458-460

The frozen-flow pattern of a dissociated gas is used in examining the effect of changes in density distribution (caused by dissociation) in the boundary layer. An expression for the limit law of friction in the dissociated gas boundary layer is derived and theoretical results are compared with experimental data.

579. Gribkova, S. I., and L. S. Shtemenko (Department of Molecular Physics, Moscow State University). Estimation of the effect of second-order approximation terms in temperature-jump experiments. — VeLUMMeAs no. 3 11-17

Comparative evaluations are presented of the heat flow parameters obtained in the first- and second-order approximations by using empirical data obtained at the Department of Molecular Physics of the Moscow University in investigations of viscous-molecular flows of rarefied gases. The heat flow is represented in the Burnett approximation. A quantitative estimate is also given of the effects caused by taking account the second-order terms on the temperature jump in the interface between the gas flow and the solid.

580. Rosenshtok Yu. L. (Leningrad). The problem of thermal conductivity with time-dependent heat transfer coefficient. — ZhPMeTF no. 1 136-137

A solution of thermal conductivity problem by an approximate integral method is given for the case of linear and exponential variation of the heat transfer coefficient and the ambient temperature.

581. Kutateladze, S. S. (Novosibirsk); A. I. Leont'yev (Novosibirsk); N. A. Rubtsov (Novosibirsk). Evaluation of the role of radiation in calculating the heat transfer in a turbulent boundary layer.

ZhPMeTF
no. 4
88-93

Heat transfer by radiation and convection in a turbulent boundary layer was analyzed. Thermal radiation from a high-temperature gas affects the temperature field in the boundary layer and consequently the conditions of heat transfer by conduction and convection.

582. Murzinov, I. N. (Moscow. Heat transfer at the stagnation point of a blunt body at low Reynolds numbers.

1964
~~ZhPMe~~TF
no. 5
139-141

On the basis of an analysis of hypersonic flow around a sphere, a parameter $N = R_0k^2$ is defined which determines the stagnation-point heat transfer at low Reynolds numbers, where R_0 is the Reynolds number related to stagnation conditions and k is the ratio of densities at the shock. A system of equations of motion and energy in the stagnation-point region is solved numerically by the Kutta-Runge method, and the results show that the heat flow depends almost exclusively on the parameter N.

583. Volosevich, P. P., S. P. Kurdyumov, L.N. Busurina, and V. P. Krus (Moscow). Piston problem in an ideal heat-conducting gas.

ZhVych MMF
v. 3, no. 1
159-169

A one-dimensional problem of piston motion in an ideal gas with given conditions on the piston is discussed. The self-similarity solutions are compared with numerical solutions of a system of partial differential equations, under the same initial and boundary conditions.

584. Punchkovskiy, V. V. Features of heat and mass transfer in the presence of a heat source which is dependent on temperature and mass content. InFZh v. 7, no. 1 66-70

A system of differential heat- and mass-transfer equations for an infinite plate with an internal heat source is solved. 1) The problem is examined as applicable to a moist dielectric plate in an alternating electrical field and is restricted to the internal problem, assuming the temperature of the medium and the moisture content to be constant. The process is governed by the heat and mass transfer characteristics and similarity criteria, as well as by the varying output of the internal heat source, which requires the introduction of dynamic criteria. The minimum electric field strength producing thermal breakdown is given. 2) Finally, the mean value of the moisture content is found for the steady-state regime, which is in equilibrium only when the argument for a thin plate is vanishingly small.

585. Murzinov, I. N. (Moscow). Temperature-profile similitude in bodies moving freely in the atmosphere with supersonic velocities at extreme altitudes. IzAN MeMa no. 1 115-120

The similitude of the temperature profiles in bodies entering the atmosphere at extremely high velocities is considered. It is shown that the temperature profiles for most of the orbit are determined by only one parameter so long as the velocity is practically constant. Similitude parameters for the temperature profiles in the presence of ablation and physicochemical transformations in the body material are discussed.

586. Kalashnikov, V. N. On the stagnation temperature of a two-phase turbulent jet in a high velocity gas stream. ZhTF v. 34, no. 1 174-182

If liquid is injected into a fast gas stream, the material in the resulting turbulent wake may lose thermal energy more rapidly by heat conductivity than it gains kinetic energy from the gas flow, with the result that the stagnation temperature in the wake may be lower than either the initial temperature of the liquid or the stagnation temperature of the gas. This phenomenon is investigated theoretically both for a plane parallel jet and for an axially symmetric jet.

GROUP B AEROTHERMODYNAMICS OF HIGH-SPEED FLOWS

B-2 Aerothermal Structural Response
Thermal Shields
Ablation and Sublimation
Injection Cooling
Instrumentation

587. Danilovskaya, V. I. (Moscow). An approximate solution of the problem of a steady temperature field in a thin shell of arbitrary shape. — 1957 IzAN OTN no. 9 157-158

An approximate solution to the problem of the steady temperature field in a thin shell of arbitrary shape and constant thickness is presented.

588. Tirskiy, G. A. Ablation of a heat-conducting wall behind a moving shock wave. — 1959 DAN SSSR v. 129, no. 5 989-992

An exact solution of the ablation problem of a flat wall behind a normal shock moving in a quiet gas with a constant velocity parallel to the wall is presented. The motions of the molten-metal film and of both its interfaces are analyzed, taking account of heat conduction into the wall and disregarding evaporation of the film.

589. Gorban', N. F., and L. N. Bronskiy. An experimental study of the melting of bodies in a hot supersonic gas flow. — InFZh v. 2, no. 7 61-66

The ablation-testing conditions of conical and cylindrical (lead and aluminum) specimens, with and without shielding, under flow temperatures up to 1000°C and speeds up to 2.7 M are explained, the experimental data are presented, and the ablation mechanism is discussed.

590. Danilova, I. N. The temperature field in an infinite hollow cylinder when the ambient temperature varies according to a broken-line law. — IzAN En. AvtT no. 1 131-133

The temperature distribution in an infinite annular cylinder varying with the ambient temperature on its outer surface according to a broken-line law, and with constant temperature on its inner surface is investigated by means of an operational method.

591. Kastelin, O. N., Ye. A. Mit'kina, and A. S. Predvoditelev. Melting of bodies in supersonic flows. IzAN En AvtT no. 2 140-141

Some experimental results on the melting of solids in supersonic flow (Mach number 1.7, temperature 88 to 89°C) obtained with models made of Wood alloy. The rate of ablation, the heat emission coefficient, and the location of the most intensive disintegration are determined.

592. Sokolova, I. N. (Moscow). The calculation of the heating of shells at high velocities. IzAN En AvtT no. 3 90-94

An approximate solution is found for the heating problem of shells stablized in a flow of gas with variable velocity, pressure, and density.

593. Vatazhin, A. B. Ablation of a plate in a supersonic or high-temperature gas flow. IzAN MeMa no. 6 7-13

The problem of ablation and sublimation of a semi-infinite plate is investigated under the assumption that the ratio of products of density and the coefficient of dynamic viscosity in both the liquid and gaseous phases (of the plate material) has a large value. The solution obtained is generalized for the case when a part of the heat flux is conducted into the body.

594. Babichev, A. I. Selecting the optimum porous-cooling regime. IzAN MeMa no. 6 147-149

The problem of finding that rate of fluid injection in porous cooling of an airfoil which will ensure a minimum heat flow through its skin is discussed. A porous plate with a constant surface temperature in a steady uniform gas flow is used as a model.

595. Szaniawski, A. Certain dynamic problems of perfect partly dissociated gases. — 1960 Arch MeSt v. 12, no. 4 483-496

Certain problems of the dynamics of ideal gases containing particles subject to dissociation are studied. The analysis of decomposition phenomena is approximated by replacing a gas mixture in which one of the gases dissociates in accordance with the chemical formula $AB \rightleftarrows A + B$, by a simplified model which, in turn, permits substitution of an equation which is analogous to the equation of phase change for the complex Guldberg-Wage chemical-equilibrium equation. The equations of state, thermal functions, and isentropic equations developed for this model are presented.

596. Tirskiy, G. A. Ablation of a semi-infinite body in plane and axisymmetric incompressible gas flows. — DAN SSSR v. 132, no. 4 785-788

A procedure is presented for obtaining exact equations describing a steady ablation regime (with a constant ablation rate) near the stagnation point and methods for solving them are outlined. The possibility of generalizing these solutions for a compressible gas flow with variable viscosity and heat-conductivity coefficients (in the gas and in the molten-metal film) is indicated.

597. Prokof'yev, V. A. (Department of Aeromechanics and gas dynamics, Moscow State University). The theory of forced harmonic small-amplitude pressure-wave propagation based on gas-dynamic Euler equations with radiative heat transfer taken into account. (I) — Ve MoU MMe no. 2 33-52

In this part (see item No. 598), the absorption, dispersion, and rate of propagation of harmonic compression waves in a perfect compressible fluid are investigated under such conditions and at such frequencies that the Bouguer "wave" number and the product of the Bouguer and Boltzman "wave" numbers can be either small or large quantities.

598. Prokof'yev, V. A. (Department of Aeromechanics
The theory of forced harmonic small-amplitude
pressure-wave propagation based on gas-dynamic
Euler equations with radiative heat transfer
taken into account. (II)

Ve MoU MMe
no. 3
31-48

In this part (see item No. 597), the absorption, dispersion, and propagation rate of pressure waves are discussed in a general case, with arbitrary values of the Bouguer and Boltzmann "wave" numbers.

599. Popov, N. N. (Department of Wave and Gas
dynamics, Moscow State University).
Discontinuity propagation in the presence of
a heat source.

Ve MoU MMe
no. 4
45-49

The problem of discontinuity propagation is studied. A general expression for the velocity and a formula for the early stage of motion are established.

600. Kiselev, K. A., and A. I. Lazarev. The temperature gradient of an infinite plate with
variable heat loss coefficients in a medium
of varying temperatures.

ZhTF
v. 30, no. 6
616-621

An analysis is presented of the problem of the heating (or cooling) for 2 hr of a plate of infinite thickness with boundary conditions of the third kind that are symmetric relative to the plane bisecting the plate.

601. Vulis, L. A. (Kazakh State University), and
Kashkarov, V. P. Local redistribution of the
total energy in the boundary layer of a compressible gas at the surface of a burning body.

ZhTF
v. 30, no. 12
1477-1484

The effect of a local redistribution of the total energy (the sum of the kinetic energy and the physical and chemical enthalpy) in the boundary layer of a compressible gas flowing

parallel to a plane surface, when a heterogeneous rate of reaction, is studied. The possible generalization of the results is considered, along with their application to turbulent flow.

602. Yeroshenko, V. M., M. G. Morozov, V. P. Matulevich, Yu. N. Petrov, and V. S. Pushkin. A gas-dynamic device—NT-14 interferometer. 1961 ~~EnI~~ AN SSSR M. 1961 51-59

The Laboratory of Combustion Physics of the Academy of Sciences USSR has built a universal NT -14 gas-dynamic testing device for shapes in subsonic and supersonic gas flows with sublimation, ablation, erosion; porous and local supply of various coolants; and with chemical reactions in the flow as well as on the surface of the body in the flow.

603. Petrov, Yu. N. Cooling of the leading face of a cylinder in supersonic flow with coolant gas feeding. EnI AN SSSR M. 1961 89-93

An experimental study was made of a supersonic flow (M = 1.7, static pressure = 0.2 atm) along a cylinder with a front face having a 2-mm opening in its center through which various gases (nitrogen, hydrogen, and argon) were fed into the boundary layer.

604. Artyukh, L. Yu., L. A. Vulis, and V. P. Kashkarov. Flow of a gas burning on the surface of a plate. InFZh v. 4, no. 3 39-45

A homogeneous, compressible gas flow past a burning plate is investigated. The previous research results in this field are generalized and supplemented. A laminar boundary layer along the plate is assumed; a normal advance of the burning front on the plate surface is disregarded because of the low burn-out

rate of the solid phase. The ignition and extinction associated with variation of Mach numbers are discussed. The problem is regarded as a limit pattern of the high-speed motion of a body in the atmosphere.

605. Shakhov, Ye. M. One-dimensional unsteady heating and melting of solid bodies moving longitudinally to their flat surface in a gas. InFZh v. 1, no. 3 46-59

A two-dimensional mathematical model is used to solve heating and melting problems and evaluate the influence of practically significant factors in this case.

606. Shakhov, Ye. M. Evaporation of a solid absorbing radiant energy. InFZh v. 1, no. 4 27-38

The one-dimensional problem of the evaporation of a solid heated by the absorption of radiant energy is discussed, assuming that the flow of radiant energy is absorbed on the surface of the body and is equivalent to the heat flow at the boundary (both depend on time and on the surface temperature of the body). Two cases of evaporation: into a vacuum and into a perfect gaseous medium are considered.

607. Tirskiy, G. A. Ablation of a body and vaporization of the melt at the stagnation point and line in dissociated air flow. ZhPMeTF no. 5 39-52

Ablation of a blunt body in dissociated-air flow at the stagnation point (axisymmetric case) and at the stagnation line (plane case) with evaporation of the molten-metal film and heat absorption by the body taken into account is discussed, assuming arbitrary dependence of thermophysical body parameters and molten-material viscosity on the temperature.

608. Tirskiy, G. A. Ablation of the leading edge of a swept-back wing in a hypersonic flow. ZhPMeTF no. 6 p. 54

Thermal disintegration of the leading edge of a swept-back wing in hypersonic flow is studied. Equations describing the disintegration process and an approximate formula for ablation rate are presented.

609. Sanochkin, Yu. V. (Mathematics Institute, Academy of Sciences USSR). Thermal ionization and electrical conductivity of gas mixtures. ZhTF v. 31, no. 2 188-193

General formulas for the initial and successive thermal ionization of gaseous mixtures were derived and analyzed. The effects of introducing impurities into the gas are evaluated. As an example, the degree of ionization and the electrical conductivity of the gas behind a shock wave propagating in argon containing small amounts of cesium and aluminum are determined. Calculated and experimental values were found to agree.

610. Tirskiy, G. A. Sublimation of a blunt body at the stagnation point in a plane and axisymmetric gas-mixture flow. ZhVychMMF v. 1, no. 5 884-902

An exact solution is given for the problem of equilibrium and nonequilibrium sublimation of a blunt body in the vicinity of the stagnation point with an arbitrary dependence of physical properties of the body on temperature. The temperature profile in the body is determined by quadratures. The solution of any specific problem in the general case is reduced to the solution of a system of three finite equations for determining the concentration, temperature on the front of evaporation, and the rate of ablation.

611. Jungowski, W. (Institute of Aerodynamics, Technical University of Warsaw), Methods for calculating stagnation temperature in a hypersonic gun tunnel. — Arch MeSt v. 14, no. 3/4 491-503

An analysis of phenomena in a gun tunnel (with a description of the method derived by Cox and Winter [AGARD Report 139]) is presented. A simplified method for calculating the stagnation temperature is briefly described.

612. Zotikov, I. A., and L. N. Bronskiy. Experimental study of heat exchange in ablation of metal and in molten-metal injection through a porous wall in a supersonic flow. — InFZh v. 5, no. 4 10-14

A study was made of heat exchange on the surface of the flat front faceplate of a hollow glass-reinforced textolite cylinder, 16 mm in diameter, being covered with a film of molten tin in a longitudinal supersonic flow. The sources of the metal film were: 1) a tin rod protruding through the center hole in the cylinder faceplate into the hole and melted by it, and 2) molten tin fed under pressure through a porous chromium plug inserted in the same hole.

613. Chakalev, K. N. Heat flow in ablation melting of a plate. — InFZh v. 5, no. 4 25-30

An approximate analytical investigation of the heat-exchange in an infinite plate of constant thickness placed in a medium with a temperature higher than the melting point of the plate material is presented. The molten material is continuously removed from the solid remainder of the plate so that a moving melting plane is formed. The dependence of the instantaneous temperature at an arbitrary point in the solid on the position of the melting plane is examined.

614. **Neyland, V. Ya.** On the effect of radiative heat exchange on ablation at the stagnation point of a blunt nosed body. — InZh v. 2, no. 4 227-231

The effect of thermal radiation in the boundary layer on ablation at the stagnation point of blunt nosed body is analyzed. The influence of radiation on other flow regions is accounted for by setting appropriate boundary conditions for the gas temperatures on the outer interface of the boundary layer and for the oncoming radiation flux.

615. **Shakhov, Ye. M.** Determining the constant melting rate of a semi-infinite solid. — InZh v. 2, no. 4 237-244

A quasi-steady regime of melting of a semi-infinite body in a high-temperature gas flow is discussed, assuming immediate removal of molten material. Approximate asymptotic expressions for the rates of ablation and of heat conduction into the solid are derived for arbitrary initial conditions.

616. **Vetlutskiy, V. N., and A. T. Onufriyev.** Cooling of radiating gas flowing in flat duct. — ZhPMeTF no. 6 29-34

Heat transfer during the cooling of a grey radiating gas flowing in a flat duct is analyzed by a previously developed diffusional approximation method. It is assumed that: 1) the gas is ideal; 2) the streamlines are parallel with the duct axis; and 3) the flow velocity is limited by the relationship $M^2 \ll 1$. Heat transfer by molecular and turbulent conduction is neglected. The system of equations was solved by A. A. Dorodnitsyn's method of integral relations. Heat-flux profiles along the duct were also obtained for the case when a cool gas is injected along the wall in a direction parallel to the hot gas flow. As an example, the wall temperature and heat flux profiles along a duct 100 cm wide were calculated only for air flows at 10,000°K, at 10 and 100 atm, and radiation cooled.

617. **Pleshanov, A. S.** Ablation of centrosymmetric solids by heat-flow. ZhTF v. 32, no. 1 106-111

An approximate method is presented for determining the law and parameters of the boundary motion caused by ablation of molten material in a heat flow past centrally symmetric bodies. A qualitative solution is reduced to determining only one dimensionless criterion independent of the melting temperature which characterizes the whole process. It is also indicated how to use the method offered for solving Stefan-type problems when heat flows on the boundaries of bodies are given.

618. **Mesgovorov, L. Ya., and V. I. Prosvirin.** Disintegration of hot metals and alloys in a hypersonic air flow. 1963 IFZh v. 6, no. 2 44-51

High-temperature (up to 1500°C) oxidation of metals and alloys in high-speed (up to M = 3) air flows, accompanied by corrosion, erosion, and burning of the material was experimentally investigated. Equipment, specimens, and techniques are described and empirical data are given.

619. **Golubev, V. A. (Moscow Aviation Institute).** A theoretical investigation of a turbulent plane-parallel jet at high temperature with dissociation and ionization. 1964 InZh v. 4, no. 6 42-50

Calculations of air flow parameters based on the solution of differential boundary-layer equations with dissociation and ionization taken into account are presented.

GROUP C FLIGHT MECHANICS

C-1 Aerodynamic Performance
Stability and Control

620. Taratynova, G. P. Motion of an artificial satellite in the presence of atmospheric drag in the earth's noncentral gravity field. — 1957 ~~USPM~~ no. 1a

A method is developed for calculating the orbit of an artificial earth satellite by means of a high-speed digital computer, taking account of atmospheric drag and deviation of the earth's gravity field from the central.

621. Barabanov, A. T., and B. A. Rayzberg. Satellite deviation from an elliptical orbit. — 1958 ~~IZVUZ~~, AvT no. 4 3-8

The deviation of a satellite from an elliptic orbit which it might follow if there were no air resistance is discussed. Only the atmospheric drag is considered as a disturbing force and because of its smallness, the method of small disturbances is used in the solution.

622. Tipei, N., and C. Guta. Motions of an Aircraft along a given trajectory. (Institute of Applied Mechanics, Bucharest). — StuCeMeAp no. 4, 855-866

The dynamic behavior of an aircraft covering motions along a given trajectory in the vertical plane is discussed. Load coefficients are determined and a synthesis is derived which can be analysed by means of the obtained results.

623. Tipei, N. Nonsteady Motion of an Aircraft in the Horizontal Plane. — RevMeAp v. 3, no. 3, 199-213

The nonsteady motion of an aircraft along a given trajectory in the horizontal plane is studied.

624. **Batrakov, Yu. V., and V. F. Proskurin.** Perturbations of artificial satellite orbits caused by atmospheric drag. — 1959, ~~Isk Sp Ze~~ no. 3, 39-46

Expressions for determining secular and periodic disturbances in the elements of an elliptic orbit of an artificial satellite caused by the atmospheric drag only, are derived, and an example of calculating the first-order disturbances is given.

625. **Lavrent'yev, M. A.** The puncture problem at space velocities. — Isk Sp Ze, no. 3, 61-65

The one-dimensional problem of determining the impulse imparted to a finite-length cylinder by a circular plate of the same diameter moving at a very high speed (50 to 100 km/sec) under assumption that the evaporation of material takes place in the impact. An analogous three-dimensional problem (small sphere and a finite-radius semisphere) is also discussed. Finite formulas in both cases are obtained.

626. **Fridlender, G. O.** A system for determining the motion parameters of a body in space. — IzAN EnAvt T, no. 6, 108-117

A system for determining the coordinates, velocities, and acceleration of aircraft moving in space is discussed. For elimination of errors caused by gravitational fields and inaccuracy of instruments, a device is proposed which is not sensitive to the effect of weightlessness.

627. **Kleyman, Ya. Z.** Steady motion of a multi-component compressible medium. — IzAN MeMa, no. 1, 50-55

The analog of the conditions of the "sound crisis", that is, subsonic, sonic, and supersonic steady motion of an n-component mixture, is considered. Local variations of parameters of a two-component medium, knowledge of which is indispensable for qualitative motion studies, are investigated, together with the problem of variations in the mass of the mixture.

628. Isayev, V. K. Pontryagin's maximum principle in thrust programming of rockets. — 1961, AVT T1, v. 22, no. 8, 986-1001

Optimum programming of the magnitude and direction of rocket thrust in two- and three-dimensional cases is discussed on the basis of Pontryagin's maximum principle. Equations of motion are derived for the two-dimensional case in terms of projections onto coordinate axes under the assumption that the rocket is a point of variable mass moving in a homogeneous gravitational field and neglecting the effect of aerodynamic forces.

629. Motulevich, V. P., V. M. Yeroshenko, and Yu. N. Petrov. The effect of electrostatic fields on convective heat exchange. — EnI AN SSSR, M. 94-103

A theoretical and experimental study was made in order to compare different quantitative data obtained by various scientists on electrostatic fields and convective heat exchange. Special attention was given to an explanation of the nature of the phenomenon which determines heat-exchange intensity due to electrical convection, experimental investigation of the effect of electrical field intensity on heat exchange, and optical study of the process by means of an interferometer.

630. Gurevich, A. V. Perturbations in the ionosphere caused by a travelling body. Isk Sp Ze no. 7 101-124

The effect produced by a body moving through a rarefied, partially ionized gas are analyzed. Variations in the neutral particle density near the moving body are calculated. Perturbations of electron and ion densities are analyzed, and the resulting electric field value is determined with and without taking into account the Earth's magnetic field.

631. Bodner, V. A., and V. P. Seleznev. Control of the motion of a body in inertial space. IzAN En Avt no. 4, 197-207

In a study of an automatic control system for programmed motion of a body in an inertial space, the moving body is assumed to be subject to forces of thrust, gravitation, and resistance. Equations are derived for the motion of the body in an inertial system of coordinates and for the motion of components in a closed control circuit (e.g., navigational systems, control-signal systems).

632. Rulev, V. A. Necessary and sufficient conditions for extremals in variational problems of aircraft flight dynamics. IzVUZ AvT no. 1, 19-26

Starting with the four necessary and sufficient conditions which must be satisfied by an extremal obtained in solving any variational problem with given boundary conditions (satisfaction of the Euler equations of motion, the requirements on the extreme values of the Weierstrass function, the Clebsch condition, and the Jacobi condition), the author proves the realizability of the last condition (the possibility of constructing a field of extremals around the given extremal), taking into account the special features usually true of variational problems of flight dynamics. Expressions are derived for the Weierstrass function for the extremals and the Clebsch condition for optimal maneuvers in the vertical plane.

633. Biryukov, Ye. A. Theoretical determination of the vibratory motion of a winged rocket. IzVUZ AvT no. 2 3-16

Theoretical determinations of the vibratory motion of a winged rocket are presented for the following cases: motion with the motor in operation for a statically stable rocket and for a statically unstable rocket, and for motion with the motor not in operation for a statically stable rocket and for a statically unstable rocket.

634. Vereshchagin, I. F. Motion of a rocket along a three-point path with constant tangential acceleration. IzVUZ AvT no. 2 35-46

Rocket motion at constant tangential acceleration along a beam rider curve is analyzed. The rocket is assumed to be directed by line-of-sight control toward a moving target so that its center of gravity is located on a straight line between the control point and the target. The analysis is limited to the case of straight horizontal target motion at constant speed, but the method can be extended readily to more complex target motions.

635. Yasinskiy, F. G. The gliding range of a winged vehicle at space velocities. IzVUZ AvT no. 3 31-37

The use of the kinetic energy of a vehicle moving at space velocity for a gliding flight is discussed. The gliding is considered as quasi-steady-state immersion in the atmosphere at altitudes of 70-75 km in unpowered flight at orbital velocity with overloads of 4 to 5 g's.

1962

636. Mikhaylov, F. A., and V. M. Strumilov. Dynamic accuracy in automatic longitudinal stability control of winged aircraft in disturbed air. MoAvI Avtom. Reg. no. 139 87-107

The accuracy attainable in automatic control (by an autopilot) of the dynamic longitudinal stability of a winged aircraft exposed to random wind disturbances is discussed. A qualitative control criterion related to structural parameters of the aircraft-autopilot system is established for determining the degree of perfection of the system.

637. Klimov, V. I. Effect of gyroscopic moments of an aircraft engine on the dynamic characteristics of an airplane. IzVUZ AvT no. 2 15-22

It is shown that gyroscopic moments of the engine can affect considerably, and even deteriorate the control characteristics of a modern airplane (with a reaction engine), so that in some cases special automatic devices for aerodynamic balancing of gyroscopic moments will be warranted.

638. Chakalev, K. N. Heating of a plate in the process of ablation. InFZh v. 5, no. 4 25-30

An approximate solution is obtained for the problem of heat transfer during the melting of an infinite plate, with ablation of the liquid phase. Relationships are obtained for determining the rate of advance of the melting front and the flow of heat into the solid part of the plate from a given temperature variation with time at some point inside the plate.

639. Makarov, O. F. Optimality of multistage rockets. IzVUZ AvT no. 4 18-26

An investigation is made of optimality conditions for multistage-rocket motion in force-free and gravitational fields. The problem of establishing optimality conditions is reduced to determining ratios of component masses at which the

attainment of a given velocity by an n-stage rocket is ensured and which minimize a given performance functional. Exponential, linear, and linear-fractional laws of mass expenditure are considered.

640. Ivanov, Yu. N. Optimum power variation in the motion of a variable-mass body in a a gravitational field. — PMMe v. 26, no. 4 780-782

Under the assumption that the initial total relative weight of the power source and fuel is known, the following variational problems are solved: to determine the laws of: 1) optimum continuous decrease in the relative weight of a power source, and 2) acceleration-vector variations caused by reactive thrust, which ensure the minimum time of motion between two given points in phase space. A system of equations with a set of boundary conditions describing the problem is written.

641. Tokarev, V. V. The effect of a random power decrease on the motion of a variable-mass body in a gravitational field. — PMMe v. 26, no. 4 783-789

The influence of a random stepwise decrease of source of power caused by damage to its sections on the motion parameters of a body of variable mass in a gravitational field is studied. The case when the power source has a large number of autonomous sections is analyzed.

642. Ostoslavskiy, I. V., and I. V. Strazheva. Dynamics of flight. Aircraft trajectories. — 1963 Dinamika poleta

This book contains methods for determining the flight trajectories of aircraft (airplanes, guided missiles, ballistic rockets, rocket planes). The trajectory optimization methods based on application

of the calculus of variations are discussed. It is a textbook for students of the higher aeronautical schools.

643. Il'in, V. A. Transfer of a space vehicle decelerated in a planetary atmosphere into a satellite orbit. InZh v. 3, no. 2 203-206

In discussion of this problem it is assumed that the gravitational field of the planet is a central Newtonian field and that the atmospheric portions of the braking ellipses are small in comparison to the total orbit. The additional thrust impulse necessary to transfer the vehicle from an elliptical orbit into a given circular orbit is determined.

644. Grodzovskiy, G. L., Yu. N. Ivanov, and V. V. Tokarev. Mechanics of low-thrust space flight (1). InZh v. 3, no. 3 590-615

The following topics are discussed in the first article concerning the mechanics of low-thrust space flight: 1) formulation of the problem of flight mechanics of vehicles equipped with solar sails, their weight ratios, transfer trajectories between planetary orbits, and escape from gravitational fields; 2) general formulation of the optimization problem in the flight mechanics of low-thrust space vehicles, their optimum weight ratios for the simplest modes of motion and a perfectly controlled propulsion system (its optimum weight proportions and power control). Seventy-three Soviet and non-Soviet references are given.

645. Grodzovskiy, G. L., Yu. V. Ivanov, and V. V. Tokarev. Mechanics of low-thrust space flight (2). InZh v. 3, no. 4 748-768
The following topics are discussed in this article on low-thrust space flight mechanics: optimum trajectories and

acceleration vectors produced by thrust in force-free and central fields, the parameters of a low-thrust perfectly controlled propulsion system in optimum trajectories. The noncontrolled propulsion systems and optimum trajectories with constant and variable accelerations produced by thrust are discussed. Forty-three Soviet and non-Soviet references are given.

645a Beletskiy, V. V. Libration of a satellite in an elliptic orbit. Isk Sp Ze 46-56

Small forced oscillations of a satellite in the plane of its orbit (caused by the ellipticity of the orbit) around its center of mass are investigated, especially with respect to resonance effects.

646. Gaushus, E. V. An investigation of a certain mode of self-induced oscillations of a spaceship. Isk Sp Ze no. 16 57-67

Plane self-induced oscillations in motion of a spaceship controlled by an impulse-type automatic system are discussed. It is assumed that the directional-deviation sensors of the spaceship have a dead zone on whose boundaries constant-intensity short-duration control impulses are produced by servos and that the perturbance moments acting on the vehicle in flight are of constant magnitude and direction.

647. Lur'ye, A. I., and M. K. Cheremkhin. The motion of a mass point under a small transverse thrust in a gravitational field. Isk Sp Ze no. 16 246-251

The motion of an aerospace vehicle (treated as a mass point) in a central gravitational field with a small transverse thrust is discussed. It is shown that by introduction of a "correction member" with a factor ε^2 (ε-is the thrust-to gravity ratio) in the equations of motion, a more exact computation of the trajectory can be obtained.

648. **Lebedev, V. N., and B. N. Rumyantsev.** Variational problem of the transfer between two points in a central [gravitational] field. Isk Sp Ze no. 16 252-256

The plane problem of the minimum-time transfer of a spaceship between two points in a central gravitational field is studied under the assumptions that acceleration (due to the thrust) is constant and that distances between the points and the gravitation center are given. Transfers between two circular orbits and from a point to a given orbit are considered.

649. **Tarasov, Ya. V.** On optimum aircraft-motion regimes. IzVUZ, AvT no. 3 34-42

The selection of a characteristic of the throttling of the engine of an aircraft in motion in which one of the characteristics of motion (e.g. velocity, altitude range, weight) reaches its extremal value is discussed.

650. **Kozhevnikov, Yu. V.** On selecting the optimal control of aircraft. IzVUZ, AvT no. 4 15-24

The problem of selecting an optimum control system for an aircraft is generalized with consideration of characteristics of controls. The motion of an aircraft about its centroid is taken into account, and the Pontryagin maximum principle is used in formulating optimization criteria.

651. **Kosmodem'yanskiy, A. A.** Variational problems of orbital-airplane dynamics. Ve MoU, MMe no. 4 70-76

The optimum regimes of circular orbital motion of an airplane, equipped with a liquid-fuel rocket engine, at high velocities ($M > 10$) and altitudes of 60 to 100 km are discussed with emphasis on the effect of aerodynamic forces on the motion parameters.

052. **Mel'ts, I. O.** The optimal aerodynamic maneuver for changing the orbital plane at near-circular velocities. — 1964, IZh, v. 4, no. 1, 3-9

The variational problem of optimizing the velocity loss during aerodynamic maneuvering at small angles of the trajectory with the local horizon is considered. Equations for three-dimensional motion of a lifting vehicle as a point mass are written. The optimum control of the angle of attack, lift-drag ratio, and banking angle are discussed and the existence of an optimum flight regime with almost constant angles of attack and of banking for the maximum lift-drag ratio is shown.

053. **Ioslovich, I. V.** On the problem of optimal rocket trajectories. — PMe, v. 28, no. 2, 373-374

The problem of determining the final mass for the given time and vice versa, for flights in horizontal and vertical planes is discussed.

054. **Smol'nikov, B. A.** Optimum regimes of retarding the rotary motion of a symmetric body. — PMMe, v. 28, no. 4, 725-734

Two methods of braking the angular motion of a symmetric body by a system of jet nozzles are discussed: braking in the shortest time, and braking minimum fuel consumption. The problem is reduced to programming the optimum thrust of jet nozzles by using Pontryagin's maximum principle.

055. Pol'skiy, N. I., and G. M. Shchegolev. Isothermal flow of conducting gas in channels.

Teplofizika Vys Tm no. 1 53-57

The author derived in dimensionless form, by variational means, relations for the extremal values of the power generated by the stream, the pressure ratio, and the electric field intensity. The effects of the induced magnetic field (the magnetic Reynolds number), of the pressure dependence of the conductivity, and of friction are also taken into account. It is pointed out that for isothermal flow with constant velocity, the dimensionless field intensity is a measure of the thermal efficiency and that the dimensionless pressure ratio is a measure of the channel broadening.

GROUP C FLIGHT MECHANICS

C-2 Re-Entry Dynamics
Re-Entry Angles
Re-Entry Velocities
Re-Entry Manouvers
Re-Entry Gliding
Re-Entry Vertical Landing

656. Yegorov, V. A. On the solution of a degenerate variational problem and the optimal climb of a space rocket. 1958 PMM v. 22, no. 1 16-26

This article gives a solution of Mayer's problem for Pfaff's equation with one free function. The solution is used for selecting the form of the rocket trajectory which yields maximum rate of climb to a given altitude.

657. Gorelov, Yu. A. (Moscow). Two classes of plane extremal motion of a rocket in a vacuum. 1960 PMM v. 24, no. 2 303-308

The conditions governing the extremal (in relation to time and mass consumption) motion of a rocket along a curvilinear trajectory are studied. The problem of plane motions is solved separately in the horizontal and vertical planes, assuming that no effect is produced by aerodynamic force.

658. Krotov, V. F. Optimal conditions for horizontal flight of an aircraft. 1961 MoVysU, Tr no. 104 54-65

The author's theory of discontinuous solutions of variational problems is applied to the study of optimal thrust programming of the horizontal flight of an aircraft to achieve the maximum flying range. The solution of the problem is reduced to determining from the class of extremals $v = v(m)$ (v being the velocity and m the instantaneous mass of the aircraft), passing through the initial and final points (m_0, v_0), (m_k, v_k) of the flight, an extremal $v = v(m)$ for which the integral defining the flight range of the aircraft has an absolute maximum. When thrust P is a nonlinear function of fuel consumption, it is shown that the maximum flight range can be achieved for special (type a) extremals which are different from ordinary continuous extremals and cannot be found by using classical variational methods.

659. New ejection seats and emergency capsules. ALit no. 3 2-4

New models of ejection (at 24,000 km/hr) seats pro-

tected by a hermetically closed capsule have been developed with the explosive charge replaced by a rocket engine. The capsule is provided with a parachute and contains emergency provisions, oxygen equipment, and a raft.

660. Tirskiy, G.A. Ablation of the leading edge of a swept-back wing in hypersonic flow. ZhPMeTF

Thermal disintegration of the leading edge of a swept-back wing in hypersonic flow is studied. Equations describing the disintegration process and an approximate formula for the ablation rate are presented.

661. L. G. Vvedenskiy and A. I. Peshkova, No. 147097. Authors certificate in aviation. 1962 BIzobr. no. 9

Controllable parachute with slit-type canopy. For improved utilization of the reactive effect during control of the canopy, the slits are made along a straight line from the lower edge of the apex with a vent in the lower edge of the canopy. The lower edge near the vent is tightened by a double cord with a sliding attachment which makes control possible by pulling up one section of the lower edge with a control cord.

662. El'yasberg, P. Ye. Determination of an orbit from two positions. IskSpZe no. 13 3-22

A full analysis of the determination of the nonperturbed orbit of a cosmic body from two given positions is presented. Considerable attention is devoted to the existence and the uniqueness (or multivalence) of the solution. Determination of the form of an orbit is analyzed for $\Delta\Phi < 2\pi$ and $\Delta\Phi > 2\pi$. Particular cases of orbit determination when D_1, D_2, and 0 are located on a straight line are studied. All possible versions of determining orbits from two given points for given $\Delta\Phi$ and Δt values are presented in tables.

663. Kislik, M. D. An analysis of the integrals of the equations of motion of an artificial earth satellite. IskSpZe no. 13 23-52

An analysis is made of the exact integrals of the equations of motion derived earlier by the author and put into a form convenient for high-speed computers for an artificial earth satellite in a normal gravitational field in the general case of motion; only orbits of real satellites are taken into consideration. This method reduces computer time by 15 to 20 times as compared with numerical integration with the same accuracy.

664. Beletskiy, V. V. Orbit of equatorial earth satellite. IskSpZe no. 13 53-60

The properties of the equatorial trajectory of an artificial earth satellite and the effect of the behavior of osculating elements (the longitude of the perihelion and the eccentricity) or the orbit on the motion of the satellite are studied.

665. Illarionov, V. F., and L. M. Shakadov. The rotation of the circular orbit of a satellite. PMMe v. 26, no. 1 15-21

The motion of a body along a circular orbit under the action of a transverse force is studied. The system of equations of the motion of a mass point in the central gravitational field was taken and the initial conditions are established on the assumption that the circular orbit of a nonperturbed motion is located in the equatorial plane. General expressions for determining the declination angle of the plane of the satellite orbit from the equatorial plane (of nonperturbed motion) are derived in terms of transverse force and of satellite velocity attained after exhaustion of the propellant.

666. Brykov, A. V. Estimating the effect of correlation between measurements of the accuracy of processing results. 1963 IskSpZe no. 16 124-135

The present study is regarded as the first step in determining the influence of the measurement correlation (the interdependence between measurement errors) on the processing accuracy. A method for

processing such data, a procedure for estimating the processing accuracy, and a method of selecting the scope and character of the optimal measurement information are described in detail, and quantitative estimates of the effect of measurement correlation on the accuracy of final results are discussed.

667. Charnyy, V. I. On optimal trajectories with many impulses. IskSpZe no. 16 257-264

The plane problem of the motion of material point in a single-center Newtonian gravitational field has been investigated under the assumption that instantaneous velocity impulses may be imparted to the point at certain discrete moments of time, and that concentric rings emanate from the center of gravity through which the optimal trajectory can pass only after certain conditions have been fulfilled.

668. Bezgin, L. S., and M. I. Ivashchenko. Approximate designing of protective shielding against meteors. Iz AN MeMa no. 1 127-129

A method of designing a protective mantle over a space vehicle to protect it against meteoritic impacts is presented. The method is based on the idea that both the meteorite and the mantle evaporate at impact. Approximate estimation of the mantle thickness and of the gap between the mantle and the wall of the vehicle is discussed.

669. Mirolyubov, G. Shock absorbing methods in manned spaceships. Izvestiya 20 Jun 1963 3-5

In an article dealing with reentry and impact overloads, G. Mirolyubov, a physician-physiologist, states that reentry overloads are more difficult to withstand

than injection overloads. Extensive experiments with men immersed in a tank of water indicated that under these conditions, muscle tonus and strength are reduced and cardiovascular activity is sharply disrupted. Since it is these very organs that resist overloads, it is necessary to be particularly accurate in determining tolerable overload forces in reentry.

670. Kozhevnikov, Yu. V. Optimization of the flight regimes and parameters of multistage rockets. IzVUZ AvT no. 3 11-20

The solution of the variational problem for the motion of a multistage rocket, under the assumptions that the stage number is given, the trajectory consists of active and passive sections, and the stage separation takes place at zero relative velocity, yielded a generalized equation for the optimum mass distribution in the individual stages. Calculation of the optimum mass distribution for maximum flight range yielded expressions which show that the angle between the thrust vector and the horizontal coordinate remains constant along the entire trajectory, even when air resistance is taken into account.

671. Akim E.L., and T.M. Eneyev. Determination of parameters of of the motion of a spaceship from trajectory measurements. KosIsl v. 1, no. 1 5-50

A statistical approach is used to solve the problem of determining the unknown parameters characterizing the motion of a spaceship on the basis of measurements carried out at certain instants. By applying the method of maximum likelihood, the problem is reduced to the solution of a system of nonlinear equations to which Newton's method and the method of steepest descent are applied. A series of important problems connected with estimating the accuracy of predicting the motion of a spaceship from the processed data of trajectory measurements is studied, and certain algorithms for estimating are derived.

672. Yarov-Yarovoy, M. S. On the solution of the Euler-Lambert equation for transfer orbits which are close to Hohmann ellipses. KosIsl v. 1, no. 1 51-54

A transfer trajectory along the unperturbed orbit between two terminal points (the starting and finishing points) is studied. A solution of the Euler-Lambert equation is sought for transfer orbits which are close to Hohmann ellipses. An iterative method for determining the root n_1 with the necessary accuracy is described. From the value of n_1, the semimajor axis and other parameters of the transfer orbit are calculated. As an example, determination of the semimajor axis of the unperturbed orbit for transfer between the location of Earth on 13 September 1962 and the location of Venus on 22 December 1962 is presented.

672a. Sagomonyan, A. Ya., On the problem of interaction between bodies at very high velocities. — 1964, DAN USSR v, 156, no.5 1053-1056

The mechanism of impact of a body of small mass on a body of large mass at speeds of the order of 5 to 10 km/sec is discussed with the aid of an impact model which makes it possible to determine the basic parameters of the impact process.

GROUP D STRENGTH OF SPACE VEHICLE COMPONENTS

Static Stress and Strain Analyses
Minimum Weight Design
Load Carrying Capacity
Thermal Stresses and Strains
Buckling

Dynamic Stresses and Strains
Dynamic Stability
Vibration and Flutter
Aeroeleasticity
Aerothermodynamics
Liquid-Filled Bodies

673. Carafoli, E. (Institute of Applied Mechanics, Bucharest), and S. Sandulescu (Institute of Applied Mechanics, Bucharest). Harmonic vibration of ailerons of general form under supersonic conditions. — 1958 ~~Arch~~ MeSt no. 6 771-782

The motion of triangular wings oscillating harmonically in supersonic flow is investigated. The harmonic oscillations of an aileron are considered as a special case in which the problem is reduced to the calculation of motions of two appropriately selected triangular surfaces.

674. Shorr, B. F. The effect of nonuniform heating under creep conditions on changes in stress distribution. — DAN SSSR v. 123, no. 5 809-812

The time-dependent variation in stress distribution caused by nonuniform heating under creep conditions is discussed for the uniaxial state of stress, taking strain hardening into account.

675. Vorob'yev, N. F. Unsteady vibration of a thin wing in supersonic flows. — IzAN OTN no. 3 153-156

A finite-span wing is studied in an infinite volume of fluid. The wing creates a small disturbance. The problem is linearized and analyzed according to the general conceptions of thin-wing theory.

676. Lebedev, A. A. Application of the "frozen-coefficient" method to investigation of the stability of nonsteady motion. — IzVUZ AvT no. 1 11-18

The method of "frozen coefficients" is applied in the simplification of linear, uniform, differential equations of the disturbed motion of a dynamic system. The application of the method is shown for the calculation of free oscillations of rockets of the V-2 type.

677. **Vakhitov, M. B.** Design for strength of a swept-back wing of monolithic construction. IzVUZ, AvT no. 1 61-68

The general strength of swept-back wings with thick skin stiffened by stringers and flanges of ribs is investigated. The skin is able to carry normal and tangential stresses which are variable over its thickness.

678. **Karavanov, V. F.** (Moscow Aviation Institute). Equations of shallow sandwich shells with a light core under finite displacements. IzVUZ AvT no. 1 69-77

Equations which describe stress-strain relationships of these shells under the assumptions that the face layers obey the Kirchhoff-Love hypothesis and the core layer is elastic and isotropic are presented. The flexural rigidity of the faces is neglected; transverse shearing and compression strains of the core are taken into account.

679. **Kopzon, G. I.** Vibration of a thin rectangular wing of high aspect ratio in supersonic flow. 1959 PMM v. 22, no. 6 810-814

Fourth-order differential equations describing the torsional-flexural strains of a thin high-aspect-ratio rectangular wing in a supersonic flow are used in wing's flutter analysis. Expressions for determining the frequency equations for a wing in vacuum and in supersonic flow are derived as well as expressions for dynamic-stability conditions.

680. **Savulescu, S. N.** (Institute of Applied Mechanics, Rumanian AS, Bucharest). Considerations on a solution of the case of an unsteady compressible boundary layer. StuCeMeAp v. 9, no. 4 867-879

Conditions are established for the external parameters of an unsteady compressible boundary layer (velocity and temperature of the external flow, and temperature at the wall) in order to extend the applicability of the Crocco solution.

681. Lyamshev, L. M. The problem of the reciprocity principle in acoustics. DAN SSSR v. 125, no. 6 1231-1234

The results of Helmholtz and Rayleigh in respect to the reciprocity principle are extended to a mathematical formulation of the reciprocity principle describing the connection between three-dimensional sources in an acoustic medium; certain external forces acting on shells, membranes, et cetera; and radiation fields created by these sources and bodies.

682. Gerasimov, I. S. On a dynamic similarity problem for a conical shell. DAN SSSR v. 126, no. 4 727-729

An elastic conical shell subjected to the action of a moving load (constantly axially symmetric pressure normal to the surface of the cone) which propagates at a constant velocity from the apex of the cone in the longitudinal direction is analyzed. Formulas are given for the bending moments and deformations.

683. Bolotin, V. V., Yu. V. Gavrilov, B. P. Makarov, and Yu. Yu. Shveyko. Nonlinear buckling stability of flat plates at high supersonic velocities. IzAN MeMa no. 3 59-64

Rectangular plates at a zero angle of attack are investigated. Aerodynamic forces are determined by asymptotic formulas which may be used for velocities of $M \gg 1$.

684. **Vakhitov, M. B.** On determining the natural modes and frequencies of a monolithic wing. IzVUZ, AvT no. 1 16-27

The modes and frequencies of free vibration of a cantilever plate of most general type (anisotropic, laminated, swept-back, with thickness varying over the chord and span) are discussed. Flexural and torsional vibrations along the chord and span are analyzed by using the Ritz and successive-approximation methods. Theoretical and empirical values of frequencies are compared.

685. **Kan, S. N.** (Kharkov Higher Military Aviation Engineering School). Stress distribution in cylindrical shells with large cutouts. IzVUZ, AvT no. 1 32-37

The state of stress around large cutouts in a circular cylindrical orthotropic shell stiffened by stringers and frames, and subjected to transversal bending and torsion is discussed. Normal (axial) and tangential forces in the skin, and the bending moments of frames (on their planes) are analyzed.

686. **Galkin, S. I.** (Novosibirsk), **V. V. Kabanov** (Novosibirsk), and **S. S. Lyashenko** (Novosibirsk). An experimental investigation of stresses in a stiffened circular cylindrical shell with a large rectangular cutout. IzVUZ, AvT no. 2 49-61

Results of an experimental investigation of a shell under concentrated load are presented. Data on normal and tangential stresses in the open and closed parts of the shell are given and compared with those determined analytically by using the V. S. Vlasov method.

687. **Sibiryakov, V. A. (Moscow Aviation Institute). Design of an orthotropic conical shell under arbitrary external loading by the V. Z. Vlasov method.** — **IzVUZ**, AvT no. 2 72-82

States of stress and of strain of an orthotropic conical shell under asymmetrical loading are determined by using V. Z. Vlasov's theory for semi-membrane medium-length shells. Equations are derived for designing them and their application is demonstrated by a sample numerical calculation.

688. **Sirazetdinov, T. K. (Kazan' Aviation Institute). Vibrations of a wing of small aspect ratio in a subsonic flow.** — **IzVUZ**, AvT no. 3 16-23

The derivation of an integral differential equation for a wing oscillating in a subsonic flow is given, and an approximate method for the case of small aspect-ratio wings is presented.

689. Vakhitov, M. B. (Kazan' Aviation Institute) Design for strength of an elastic monolithic wing. — IzVUZ, AvT no. 3 24-32

Stress-strain relationships are discussed in an elastic monolithic wing with thick skin stiffened by ribs and stringers using a cantilever anisotropic plate as a model. The formulas derived can be also used for determining the wing loading, the aerodynamic coefficients with consideration of the effect of deformation, et cetera.

690. **Kornishin, M. S. (Kazan), and Kh. M. Mushtari (Kazan). An algorithm for the solution of nonlinear problems of the shallow-shell theory.** — **PMMe v. 23, no. 1 159-163**

A description of the algorithm for solving a system of nonlinear algebraic equations is presented and applied to investigation of the considerable flexure of a rectangular, shallow, simply supported panel under uniform transverse loading. The numerical calculations were carried out on a Strela computer.

691. Rakhmatulin, Kh. A. The propagation of elastoplastic waves in a half-space. — PMMe v. 23, no. 419-424

An approximate method is developed for solving the problem of elastoplastic waves propagating in a half-space with normal pressure along the boundary equal to zero. Three examples are analyzed, and the state of stress in the neighborhood of the load boundary is calculated.

692. Chao, Hwei-Yuan. Thermal stresses in shells of revolution with variable elastic properties. — Scientia Sinica v. 8, no. 4 383-400

Thermal-stress analysis in shells of revolution made of a material possessing a linearly time-dependent Young's modulus and a constant Poisson ratio is presented. The temperature gradient is axially symmetric over the shell and constant along its thickness.

693. Carafoli, E. (Institute of Applied Mechanics, Bucharest), and S. Sandulescu (Institute of Applied Mechanics, Bucharest). Aerodynamic characteristics of ailerons subject to harmonic oscillatory motion at supersonic speeds (supersonic flutter). — StuCeMeAp v. 10, no. 1 13-40

Aerodynamic characteristics of ailerons

subject to harmonic oscillatory motion at supersonic speeds was studied. Oscillatory motion of a polygonal aileron was found to be equivalent to that of two triangular surfaces; all forms of ailerons are calculable by a specifically developed equation.

694. Slobodkin, A. M. (Moscow). Stability of an elastic beam with rigid empennage in a supersonic flow. — 1960 InZh v. 27, 77-80

The stability of an elastic beam with a constant cross section and mass per unit length with rigid empennage moving along its axis at high supersonic speed is investigated.

695. Mouchan, A. A. (Moscow). The behavior of complex values in the problem of plate flutter. — InSb v. 27 70-76

The results of complementary calculations in the domain of high supersonic speeds are given. These results may be used for investigating the experimental data concerned with flutter of the supersonic aircraft structural covering.

696. Bolotin, V. V. (Moscow). Nonlinear flutter of plates and shells. — InSb v. 28 55-75

Nonlinear hypersonic flutter (hard and soft) of plane and curved panels, with pliable and perfectly rigid stiffening is investigated in flows with very high Mach numbers. Expansion of the middle surface and buckling of the panel caused by aerodynamic heating are taken into account.

697. **Gerasimov, I. S.** (Moscow). Elastoplastic axisymmetrical strains in a closed circular cylindrical shell. InSb v. 28 241-246

The elastoplastic behavior of a circular cylindrical shell with plane bottoms, subjected to a combination of: internal pressure, radial compression of the bottoms, and external pressure on the bottoms is investigated. The joint deformation, the elastic deformation of the shell, and the elasto-plastic deformation of the bottoms are investigated.

698. **Mouchan, A. A.** Effect of aerodynamic damping on supersonic skin flutter. IzAN MeMa no. 1 175-177

Aerodynamic-damping effects on the flutter speed of a circular cylindrical shell moving axially in a gas at supersonic speed and performing additional axisymmetrical small movements are discussed. It is shown that the error caused by disregarding aerodynamic damping can reach considerable values.

699. **Morozov, M. G.** Acoustical radiation of cavities in a supersonic flow of air. IzAN MeMa no. 2 42-46

Schlieren photographs of the supersonic flow patterns over a plane surface with cavities of various shape, depth, and attitude obtained in a wind tunnel at $M = 1.7$ and $Re = 1.2 \cdot 10^5$ are presented and discussed.

700. **V. A. Sibiryakov.** (Moscow Aviation Institute). Determining thermal stresses in a conical shell. IzVUZ, AvT no. 1 72-82

Elastic thermal stresses in a constructionally orthotropic circular conical

shell placed in a gas flow are determined by using semimembrane shell theory. Constant temperature over the wall thickness, and a modulus of elasticity and a coefficient of thermal expansion which are independent of temperature are assumed.

701. Karavanov, V. F. (Moscow Aviation Institute). Stability of shallow cylindrical light-weight-core sandwich panels with clamped longitudinal edges under axial compression. IzVUZ, AvT no. 2 50-60

Analyzing the stability of finite-length and infinite shells, the effect of transverse deformation of the core is neglected, and the flexural rigidity of the face layers is taken into account.

702. Malakhovskiy, R. A. (Gomel'). The design of orthotropic circular conical shells. IzVUZ, AvT no. 2 61-68

Stress distribution is analyzed in an elastic thin-walled conical shell stiffened by stringers and frames. The S. N. Kan method of designing cylindrical shells is generalized. The torsional rigidity of stiffening elements and eccentricity of the stiffening system toward the skin are neglected. The equivalent thicknesses and moments of inertia are constant in a cross section, but arbitrarily variable in the axial direction.

703. Shchetnikov, Ye. S. On the speed of sound in gaseous media with relaxation processes. IzVUZ, AvT no. 2 110-117

The speed of sound in a reacting gas with vibratory degrees of freedom is investigated. The case of a gas mixture consisting of partially dissociated diatomic gases with excited vibratory degrees of freedom is considered.

704. Rapoport, L. D. (Ufa). Determining the free vibrations of non-prestressed circular cylindrical shells. — IzVUZ, AvT no. 3 43-50

Natural frequencies of transverse vibrations of circular cylindrical shells of arbitrary length are exexamined in cases of simply supported, clamped, and free edges as well as for combinations of these boundary conditions.

705. Manokhin, D. G. (Kazan' Aviation Institute). Approximate determination of thermal stresses in thin-walled structures. — IzVUZ, AvT no. 3 124-134

A cylindrical thin-walled beam with airfoil cross section, longitudinally and laterally stiffened, is under discussion. The temperature varies along the contour of the cross section, but is constant over the thickness of the skin and stiffeners.

706. Malkina, R. L. (Urals Polytechnical Institute). Forced vibrations of cylindrical shells. — IzVUZ, AvT no. 4 51-60

Forced vibrations of circular and noncircular closed cylindrical shells are discussed. Pure flexural vibrations caused by shaking forces normal to the middle surface are examined, neglecting the shell of tangential inertial forces.

707. Bolotin, V. V. (Institute of Mechanics, Academy of Sciences, USSR). The edge effect in elastic shells under vibration. PMMe v. 24, no. 5 831-842

The theory of the dynamic edge effect (for example, clamping) is presented. Classification of various types of the effect for shells with positive, zero, and negative Gaussian curvatures is given. Methods for evaluating the edge effect characteristics in the vicinity of distortions are discussed.

708. Bublik, B. N., and V. I. Merkulov. (Kiev). On dynamic stability of liquid-filled thin elastic shells. PMMe v. 24, no. 5 941-946

The problem is reduced to the solution of the energy equation by a variational method, and a system of four differential equations is obtained as a result. Dynamic-stability analysis of a simply supported circular cylindrical shell filled with liquid is presented as an example.

709. Carafoli, E., and S. Sandulescu. Harmonic oscillation of tail units in supersonic flow. StuCeMeAp v. 11, no. 3 557-568

The problem of low-frequency and small-amplitude oscillation of a tail assembly in supersonic flow is reduced to investigation of certain higher-order conical motions. The particular case of oscillation with subsonic leading edges is discussed. The interaction between vertical and horizontal control surfaces is considered.

710. Savin, G. M., Van-Fo-Fy, and V. M. Buyvol. 1961 DopAN UkrSSR no. 11 1435-1439

A successive approximation method of

analyzing the stress distribution around two unequal circular holes in a shallow spherical shell under constant internal pressure is presented. The superposition of stresses in an intact shell and of stresses caused by each hole is used to obtain the final state of stress. A numerical example and a diagram illustrate the discussion.

711. Lyubimov, V. M. (Moscow). Some exact solutions of the problem of self-sustained vibrations of a swept-back wing in a supersonic gas stream. InSb v. 31 171-178

A bending-torsion model (a cantilever beam of variable rigidity in bending and torsion) is used for vibration analysis of a swept-back constant-chord wing by applying the piston theory to account for the effect of aerodynamic forces, assuming the coincidence of the flexural axis with the line of centroids (of cross sections). The particular cases of pure torsional, pure flexural, and combined vibrations are discussed.

712. Kislyagin, N. N. Downwash produced by a wing in an unsteady flow. IzAN MeMa no. 4 20-25

The concept of coefficients of rotary derivatives is introduced in a method proposed for determining the downwash produced by a rigid or an elastic wing of arbitrary shape in unsteady flow of an ideal fluid. Approximate formulas based on the linear theory of flow are derived for calculating aerodynamic forces and moments acting on the wing-empennage system, taking into account the downwash effect.

713. Ambartsumyan, S. A., Zh. Ye. Bagdasaryan. Stability of orthotropic plates in a supersonic gas flow. IzAN MeMa no. 4 91-96

Nonlinear flutter of a plate in a supersonic flow is discussed. The influence of transverse slips on the character of flutter is accounted for. The problem is solved in its linear version by variational methods.

714. Biryukov, Ye. A. Theoretical analysis of oscillatory motion of a winged rocket. IzVUZ, AvT no. 2 3-16

The oscillation of a winged solid-fuel rocket in the vertical plane caused by some disturbance (for example, moving the elevator, switching the engine on and off, sudden changes in the eccentricity of the thrust) in its steady flight is discussed, assuming that the angles of incidence of the wings and the control surfaces are fixed, thrust eccentricity is constant, and the mass and centroid of the rocket do not change during the flight.

715. Vakhitov, M. B. (Kazan' Aviation Institute). Designing a monolithic wing with a set of nonparallel stringers for strength. IzVUZ, AvT no. 2 47-58

The strength of a swept-back wing with thick skin, parallel ribs, and nonparallel stringers, as well as wings with a central section are under discussion. The previous works of the author (1958) on the strength of wings with orthogonal stiffening elements are generalized.

716. Figurovskiy, V. I. (Moscow Aviation Institute). A design method for a conical shell clamped on a part of its cross-sectional contour. IzVUZ, AvT no. 2 67-77

The stresses in a conical shell, similar to a wing with a large taper and low aspect ratio stiffened with stringers and frames (on ends) are analysed. In the root section, the skin is clamped on a part (about the middle) of the contour, the parts adjoining the leading and trailing edges are supported by a rigid rib. The shell is symmetrical to the horizontal middle plane and has a low thickness-to-depth ratio.

717. Yershov, V. V. Cylindrical flexure of unsymmetrical light-core sandwich plates. IzVUZ, AvT no. 3 38-55

A stress analysis of rectangular sandwich plates in a state of slight cylindrical flexure is presented. The outer layers are of different materials and unequal thickness; their flexural rigidity is neglected. The core material is not resistant to longitudinal forces and bending moments, and its modulus of elasticity is far smaller than those of the outer layers.

718. Karnozhitskiy, V. P. The effect of thermal stresses on the stability of a sandwich wing panel. IzVUZ, AvT no. 3 69-77

The thermal buckling of aerodynamically heated wing skin, of sandwich construction, between spars and two neighboring ribs is investigated. The skin, free of external loading, is compressed in the direction of the span by uniformly distributed forces.

719. Matyushev, Yu. S. Design for strength of a conical shell shaped like a low-aspect-ratio wing. IzVUZ, AvT no. 3 89-99

An analysis of the stresses in a constant-thickness, tapered, thin shell with the shape of a low-aspect-ratio wing is presented. Equations are derived by using Vlasov's variational method assuming uniform stress distribution over the thickness of the shell.

720. Gur'yev, N. I. Calculation of cylindrical and prismatic shells by the method of discrete unknowns. IzVUZ AvT no. 3 153-154

An engineering method is presented for calculating thin-walled shells of arbitrary cross-section (open and closed, long and short), with constant or variable wall thickness. This method consists in assigning a finite number of degrees of freedom to a transverse shell element and an infinite number of degrees of freedom to a longitudinal element. The unknown state of stress is approximated in the form of two states: 1) the principal, determined by the elementary theory of thin-walled strips; and 2) the secondary, investigated by an energy method, with the use of Castigliano's variation principle.

721. Il'gamov, M. A. (Kazan'). Forced vibrations in shallow sandwich panels. IzVUZ, AvT no. 4 58-65

An analysis of forced vibrations in a shallow rectangular simply-supported sandwich panel with a symmetrical structure is presented, taking into account the energy dissipation in the cone only, which is assumed to be absolutely plastic in its plane but incompressible over its thickness.

722. Vakhitov, M. B. On the investigation of stress distribution in monolithic wings. IzVUZ, AvT no. 4 128-131

Effect of nonuniformity in location and

strength of stringers (or spars) along the chord of the wing on the stress distribution in skin is discussed in cases of straight, swept-back, and triangular wings. The effect of location of flexural (elastic) axis on stress distribution in skin along the span is examined for each of above cases.

723. Gabril'yants, A. G., and V. I. Fedos'yev. Axisymmetrical equilibrium configurations of uniformly compressed spherical shells. PMMe v. 25, no. 6 1091-1101

The buckling behavior of an elastic shallow spherical shell under uniform external pressure is discussed. The solution obtained is independent of the R/h ratio. A dimensionless pressure parameter and the relative local deflection are used to illustrate graphically the pressure-deformation relationship. A critical review of Soviet and non-Soviet data on this problem is given.

724. Petre, A. C., Stanescu, C., and L. Librescu. (Physics Institute, Rumanian Academy of Sciences). Aeroelastic divergence of multicell wings taking their fixing restraints into account. RevMeAp v. 6, no. 6 689-698

Aeroelastic divergence of lifting surfaces of constant cross-section is analyzed with consideration of the span-wise variation of the twisting moment as well as the effect of restraints at the root cross section.

725. Kan, S. N. The strength of closed and open cylindrical shells. RaPro, Sb no. 6 M. 1961 213-246

An approximate method is presented for the design of cylindrical and prismatic shells

of closed and open cross sections, stiffened by diaphragms rigid in their own planes. The transverse loading, longitudinally and laterally variable, may be either continuous or by concentrated loads (as a particular case). The support conditions are arbitrary.

726. Aksel'rad, E. L. Large axisymmetrical deflections of a heated shallow shell of revolution under loading. RaPro, Sb, no. 6 M. 1961 275-278

The general problem of determining large deflections under transverse axisymmetrical loading of a shell with the elasticity modulus and Poisson's ratio varying along the thickness of the shell, causing a variable thermal expansion in that direction during heating, is considered. The deformations of a simply supported shell of arbitrary profile, with and without a hole at the top, determined by a quadrinomial are investigated. The approximate Bubnov-Galerkin method is used to study the large axisymmetrical deflections of a shell under these conditions.

727. Ogibalov, P. M. (Department of Elasticity Theory, Moscow State University). The problem of flutter of shells and panels. VeLUMMeAs no. 5 60-65

A brief survey of investigations on flutter is presented. The problem is stated on the basis of A. A. Il'yushin's law of plane sections for supersonic aerodynamics.

728. Tskhovrebadze, D. S. Designing circular cylindrical shells. 1962 AN GruzSSR Soob, v. 28, no. 6 641-648

An analysis of the stress-strain relationships of very thin shells

(where the thickness-to-radius ratio is negligible in comparison to unity) begins with a system of equilibrium equations of an elastic body in non-dimensional coordinates. By application of I. N. Vekua's method of reducing the three-dimensional problem to a plane problem, the relationships among the so-called moments of component stresses, strains, and displacements are obtained instead of these quantities themselves.

729. Palley, I. Z. The effect of the history of loading on state of stress in two-layer shells. AN LatSSR. IAvMe, Sb. no. 9 115-126

An investigation is made of the influence of sequence in the application of component loads (e.g., heating and pressure) to a two-layer shell beyond the proportional limit on the stress-distribution pattern.

730. Lebedev, Yu. A. The simplest cases of structural damping in joints of thin-walled members. AN LatSSR IAvMe, Sb. no. 9 5-14

The dissipation of vibrational energy interfacial Coulomb slip damping in skin joints with beam flanges or stiffeners is discussed. The rigidity effects of elastic joining elements (e.g., rivets or fitted-body screws) is taken into consideration.

731. Broude, B. M. Practical methods of shell design for stability. AStr Ar SSSR IStr Tr no. 13 38-69

The development of practical methods for use in analyzing the buckling stresses and critical loads in shells under various loading conditions is discussed. It is assumed that the shells were in a

membrane-stress state prior to buckling. Conventional analysis procedures and mathematical tools used in practice are outlined, and the suitability of either the Galerkin-Papkovich or the Ritz method for buckling analysis in both the linear and nonlinear formulation of the problem is explained.

732. Petukhov, V. G. A method for accelerated determination of the life of an aircraft structure. — B Izobr no. 22

Strain gauges are used to measure stresses in a plastic specimen attached to a structural member of the aircraft in flight and to an identical member of the aircraft tested in a laboratory under repeated static loading to destruction of the specimen. The two sets of data are then compared; a conversion factor is calculated, and the number of flight hours corresponding to one loading cycle is obtained.

733. Borshchevskiy, A. P. A flight-safety system which signals the occurrence of fatigue cracks in the rotor-blade longerons to the pilot of a helicopter. — B Izobr no. 22

The longerons, hermetically sealed and filled with air compressed to a pressure > 1 atm, contain pickups connected to an indicator in the cabin which respond when cracks appear and pressure drops.

734. Obremskiy, S. V. The effect of stiffening rings in a closed cylindrical shell taken directly into account. — DopAN UkrSSR no. 7 883-887

It is shown how the effect of elastic stiffening rings in a closed circular cylindrical shell may be taken directly into account in the application of V. S.

Vlasov's variational method, with shear strains also considered. The assumption, different from that of Vlasov, is that some of the rings have finite rigidity both in their own plane and when deformed beyond it.

735. Guz', O. M. Stress concentration at a hole with a nipple in an orthotropic cylindrical shell. DopAN UkrSSR no. 12 1594-1597

Stress distribution on the edges of a circular hole stiffened by a rigid nipple is analyzed by the Ritz method. The shell is under uniform internal pressure. The theory of shells with a large index of variation is applied, and the effect of the orthotropy of the material and of the nipple on the stress distribution around the hole is analyzed.

736. Shorr, B. F. (Engineering Physics Institute, Moscow). Designing for creep under nonuniform heating. InFI. Sb. M. 1962 183-240

The determination of creep stresses and strains, as well as their cross-sectional and axial distribution in bodies subjected to nonuniform heating, is discussed. The application of creep theories to the investigation of the behavior of nonuniformly heated bodies in a state of steady and transient creep is considered.

737. Makhovikov, V. I. Thermoelasticity problem of a plate. InFZh no. 3 95-102

The thermal stresses in an elastic, isotropic plate without external loading in a stationary temperature field are analyzed. Thermal stress concentrations around circular and square holes in an unbounded plate with an infinite number of holes are also discussed.

738. **Yel'pat'yevskiy, A. N., and V. V. Vasil'yev. Designing prismatic shell structures in terms of stresses.** InZh v. 2, no. 1 117-129

Castigliano's principle is applied in developing a variational method of stress analysis of the membrane-stressed cantilever shell structure of a box-type multicell cross section.

739. Omitted. See page 242 + 740.

740. **Uzdalev, A. I. Plane thermoelastic problem of an anisotropic body.** InZh v. 2, no. 2 280-286

The elastic equilibrium of a homogeneous-thickness plate, anisotropic for both elastic and thermal effects, is analyzed. The plate is in a state of plane stress caused by external forces and a stationary temperature field. The material of the plate has a linear stress-strain relationship; there are no body forces. The plate region is multiply connected (holes in the plate), and the temperatures on the closed contours are given.

741. **Bolotin, V. V. On the behavior of heated plates and shallow shells in a gas flow.** InZh v. 2, no. 3 119-125

The thermal buckling and flutter of a rectangular aircraft skin panel under kinetic heating in a supersonic gas flow and internal pressure is investigated, taking account of the flow pressure on the distorted skin. The behavior of a steel skin under real flight conditions is briefly discussed.

742. Durgariyan, S. M. Thermal stress analysis of thin orthotropic shells of revolution. InZh v. 2, no. 3 126-140

The axisymmetrical problem of thermoelastic stress-strain relations in thin orthotropic shells of revolution with a positive Gaussian curvature and low thickness-to-radius ratio is treated in a linear formulation, with time-variable coefficients of elasticity and thermal expansion.

743. Yelpat'yevskiy, A. N. Investigating the state of stress in two-layer cylindrical shell. InZh v. 2, no. 3 141-149

A plain cylindrical shell strengthened by an outer layer of fiber-reinforced plastic is discussed. The whole shell is under internal pressure and an axisymmetrical temperature field. The stress distributions in both layers are determined and relationships ensuring minimum weight of the shell are established.

744. Abramyan, B. L., and A. A. Babloyan. Stress and strain in a hollow cylinder. IzAN Arm SSSR, FMN v. 15, no. 2 87-99

An exact general solution is presented of the axisymmetrical problem in the elasticity theory for a hollow circular cylinder of finite length under arbitrary external load, with given normal displacements and tangential stresses on its faces. The derivation of general-form equations for stresses and strains in terms of the Fourier and Fourier-Dini series is presented.

745. **Arutyunyan, N. Kh.** Torsion of thin tubular shells. IzAN Arm SSR, FMN v. 15, no. 2 101-109

The torsion of long, thin, cylindrical shells of arbitrary-contour closed cross section is investigated. The small-parameter method used here allows appraisal of the validity of approximate formulas (e. g. Bredt's); it gives solutions in cases where Bredt's formulas cannot be used, and accounts for stress concentration in fillets of polygonal cylindrical shells.

746. **Sarkisyan, V. S.** The deflection of long elastic plates at constant supersonic velocity. IzAN ArmSSR, FMN v. 15, no. 2 139-152

The small parameter is used in the approximate solution of the deflection problem of a thin, narrow plate of an arbitrary symmetric form, fixed at the edges and moving in a gas with constant supersonic velocity, at a fixed angle of attack. The problem of determining the deflection function is reduced to the solution of a fourth-order partial differential equation with certain boundary conditions.

747. **Bagdasaryan, Zh. Ye.** The stability of a cylindrical shell in a supersonic gas flow. IzAN ArmSSR FMN v. 15, no. 6 3-10

The elastic stability of a thin circular shallow shell is analyzed. The material of the shell is orthotropic and obeys the generalized Hooke's law. There is an undisturbed supersonic compressible-gas flow along the shell. The hypothesis of the preservation of the normals is accepted. Cases of symmetrical and nonsymmetrical buckling are discussed, and formulas for the minimum critical velocities are given.

748. **Kordashenko, A. B.** The stability of stiffened shells (USSR). IzAN MeMa no. 1 115-120

In a study of the stability of double-curvature shells with arbitrarily located stiffeners, the state of stress of the shell itself is examined by the use of the principle of virtual displacements; a variational equation is obtained which furnishes the differential equations of elastic stability of a shell with an arbitrary initial (precritical) state of stress.

749. **Mushtari, Kh. M.** Making the approximate theory of sandwich plates more exact. IzAN MeMa no. 1 125-130

The state of equilibrium of a sandwich plate with elastically orthotropic face layers and a light core is discussed, with core compressibility taken into account. An approximate formula of the critical forces of both face layers is derived. An exact formula for these forces is also presented and its derivation is outlined. The values of critical forces obtained by approximate and exact formulas are compared with values given by other authors.

750. **Sokolov, F. A.** A spherical axisymmetrically loaded shell. IzAN MeMa no. 2 150-157

Two cases of a spherical shell under a symmetrical load are analyzed: 1) a shell with a small circular hole at the top; and 2) a closed shallow shell (without a hole). It is assumed in case (1) that there is no interaction of the edge of the hole with the edge of the shell or with any other cross section. A suggestion is made on how to apply this method for large central angle of the hole (large holes). In case (2) there are no special conditions on the top.

751. **Bolotin, V. V.** Unsteady flutter of plates and shallow shells in a gas flow. IzAN MeMa no. 3 106-113

The unsteady flutter of plates and shallow shells in supersonic gas flows is discussed. Solutions are sought for transient regimes with simultaneously variable parameters of velocity, density, and temperature. Approximate equations for the flutter amplitude and phase are derived.

752. **Bolotin, V. V.** The effect of membrane stresses in thin shells on their natural vibrations. IzAN MeMa no. 4 52-60

An asymptotic method is used in investigating the spectra of natural vibrations of thin elastic shells, with the initial membrane stresses in the middle surface taken into account. The known initial equations for deflections comparable with the shell thickness are used.

753. **Mushtari, Kh. M.** The theory of shallow sandwich shells with layers of variable thickness. IzAN MeMa no. 4 71-76

Generalized expressions for stress-strain relationships in nonsymmetrical sandwich shells with nonuniform temperature fields are extended to shells with variable-thickness face layers and minimal volume (weight).

754. **Balabukh, L. I., and L. A. Shapovalov.** Contact problems of stiffening membrane-stressed shells of revolution by rings. IzAN MeMa no. 4 77-90

The flexure and stability of circular rings used for stiffening membrane-stressed shells of revolution are examined

from the standpoint of contact problems. A general discussion is presented of an elastic system consisting of two arbitrary membrane-stressed shells of revolution joined together by an inextensible circular ring which is continuously loaded by the action of the shells.

755. Vasitsyna, T. N. The stability of an axially compressed cylindrical sandwich-type panel. IzAN MeMa no. 4 137-139

Stability equations previously derived for nonsymmetrical shallow sandwich-type shells with orthotropic face layers and orthotropic rigid cores are used to investigate the stability of a shallow cylindrical panel with a light-weight isotropic core layer and isotropic face layers of different thicknesses.

756. Landa, P. S., and S. P. Strelkov. Flutter of a wing under nonlinear aerodynamic forces. IzAN MeMa no. 5 111-117

Results of investigating the effect (on an electronic analog computer) of flexural-torsional flutter of a cantilever wing with a nonlinear dependence of aerodynamic forces at hypersonic speeds on the angle of attack are presented. The dependence of the flutter speed on wing parameters and initial disturbances is obtained, and the effects of the value of the ratio of flexural to torsional frequencies and of the presence of the fuselage are discussed.

757. Razzhivin, K. A. Stress distribution in an open circular cylindrical shell clamped on straight edges. IzAN MeMa no. 5 147-150

An approximate method is presented for

determining the state of stress in a shallow, circular shell under arbitrary loading, with clamped straight edges with exactly satisfied arbitrary boundary conditions on the circular edges. A sample strain analysis is given for a long, shallow, circular cylindrical shell clamped on all [four] edges under the following loadings normal to its surface: uniform continuous, hydrostatic, and that caused by wind.

758. Durgar'yan, S. M. On thermal stress analysis of an orthotropic plate with consideration of transverse shear. IzAN. MeMa no. 6 154-160

The effect of transverse shear on thermal stresses in a rectangular orthotropic plate is analyzed under the assumptions that elasticity constants and the thermal expansion coefficient of the material are temperature-dependent, and that the strains over the plate thickness are determined by free thermal expansion. The shear-stress-distribution functions are given.

759. Aleksandrov, A. Ya. An analogy between stress functions in elasticity theory. IzAN SibO no. 2 15-24

An analogy between stress functions of the axisymmetrical and plane problems of elasticity theory is established. Some new solutions of the axisymmetrical problem of an infinite, hollow, heavy cone are found for solid or hollow semi-infinite wedges. The problem is worked out in polar (plane and spherical) coordinates. It is shown that the proposed method also makes possible an analogous solution in other coordinates.

760. Malkina, R. L. Plates and shells under vibrational loading. IzVUZ no. 1 57-65

Under discussion is the behavior of circular and rectangular thin plates and of cylindrical and shallow spherical shells under the action of forces changing according to a harmonic law. The proposed method of analysis is based on the fact that all normal forced vibrations of the system are of the same frequency and phase.

761. Yershov, V. V. The stability of asymmetrical sandwich plates. IzVUZ, AvT no. 1 120-124

A rectangular sandwich plate, supported along two opposite edges and compressed by forces applied at these edges, is discussed. The determination of the critical forces is based on equations and relationships established by Kh. M. Mushtari, without taking account of the flexural rigidity of the outer layers and the compressibility of the core.

762. Kabanov, V. V. The stability of a circular cylindrical shell in a nonuniform temperature field. IzVUZ, AvT no. 2 65-71

The local stability of a long circular cylindrical shell subjected to longitudinal forces variable along the circumference (due to heating) is studied. A sample analysis of the thermal stability of a shell partially filled with liquid at 0°C and surrounded by a medium of arbitrary temperature is given.

763. Sverdlov, A. I. (Moscow Aviation Institute). The design of a stiffened cylindrical shell under concentrated loads. IzVUZ, AvT no. 2 72-85

The state of stress in a circular cylindrical shell stiffened by stringers and by frames under concentrated loads applied

to longitudinal beams on the outer surface, is examined. Stresses in the beam and shell are analysed by applying Castigliano's principle to the beam-shell system.

764. Sivchikov, B. Ye. Static-flexure and free-vibration equilibrium equations of irregularly-shaped cantilever plates. IzVUZ no. 2 86-94

The application of the variational Lagrange equation in the analysis of flexure and vibration of a uniform-thickness cantilever plate by substituting the deflection in polynomial form (thus obtaining a system of ordinary linear equations) is generalized to the case of a variable-thickness irregularly shaped quadrangular plate with straight edges located arbitrarily relative to each other.

765. Akhmed'yanov, I. S. A method for integrating flexure equations of a spherical shell IzVUZ, no. 3 62-70

A new method for the exact integration of equations which describe the flexure of spherical shells under symmetrical loading and arbitrary boundary conditions is discussed. The simplified solution of basic equations gives the expressions for forces and moments per unit length, as well as for strains and displacements, in series form.

766. Yefimov, I. A. Plastic stability of a corrugated-core cylindrical sandwich shell under combined loading. IzVUZ, no. 3 79-86

The stability in the small of a simply supported circular cylindrical sandwich shell under external pressure combined with axial compression is investigated. The core layer is made of corrugated sheet material. Its strains are assumed to be in the elastic range at the instant of the loss of stability, while the conventional face layers are

strained beyond this range. The corrugated core is treated as an orthotropic solid having equivalent elastic characteristics, and the flexural rigidity of the isotropic face layers is taken into account.

Sivchikov, B. Ye. Variational method for analyzing static flexure and free vibrations of a cantilever plate. IzVUZ, AvT no. 3 102-110

The static flexure and free vibrations of a rectangular, elastic, continuously loaded, rigid plate of variable thickness (in both longitudinal and lateral directions) with its clamped edge nonparallel to the free-end (lateral) edge are analyzed, and the effect of root beveling on the flexural and vibrational behavior of this swept-wing-form plate is examined.

Burmistrov, Ye. F. An analysis of structurally orthotropic shells of revolution. IzVUZ, AvT no. 4 57-67

By starting with equilibrium equations for shells of revolution and using the relationships between elastic forces and the strains of the middle surface of structurally orthotropic shells of revolution, as well as between strains and displacements, a general solution of shell-behavior problems is obtained. A multilayer shell with an odd number of orthotropic layers symmetrical about the middle surface and a two-layer shell with isotropic layers of different elastic properties are treated as special cases of the general solution.

9. Il'gamov, M. I. Equilibrium and vibration equations of asymmetrical sandwich shells. IzVUZ, AvT no. 4 68-78

Thin asymmetrical sandwich plates with orthotropic outer layers and an orthotropic core are discussed, taking into account the linear deformability of the core over its thickness. Free vibration and stability of a sandwich are analyzed

by using the equations derived. A numerical example of calculating the critical loading of an infinite thin sandwich plate in symmetrical and skew-symmetrical buckling is given.

770. Sachenkov, A. V. Determining the lower buckling loads of thin shells. IzVUZ, A... no. 4 111-122

An approximate method is proposed for determining the lower critical load in local buckling of thin shells. The anisotropy of the material and effect of initial imperfections of the middle surface are taken into account.

771. Gerasimov, I. S. (Institute of Mechanics, Academy of Sciences, UkrSSR). The effect of a moving load on a conical shell. IzVUZ M no. 4 33-37

It is assumed that an elastic infinite circular conical shell with a wall thickness proportional to the distance from the vertex is under a constant axially symmetric pressure which is moving with constant velocity from the cone vertex in the direction of its axis. An infinitesimal element of the conical shell is analyzed in a movable coordinate system. Displacements, stresses, and bending moments are determined.

772. Twardosz, F. (Gdansk Polytechnical Institute). The dynamic stability of a conical shell under longitudinal and transverse continuous pulsating loads. Mekhanika no. 5 3-82

Equations of the dynamic stability simply supported thin conical shells are derived from equations of their static stability. Equations for critical frequencies are also derived, and resonance ranges are determined.

773. Kan, S. N. Flexure of circular cylindrical shells. PMe v. 8, no. 1 3-11

The flexure of solid and sandwich-type circular cylindrical shells stiffened by diaphragms rigid in their own planes is discussed under arbitrary support conditions, and external loading varying in axial and lateral directions.

774. Kovalov, K. V. The effect of a stiffening ring in a cantilever circular cylindrical shell. PMe v. 8, no. 1 12-19

Cylindrical shells with a length 1 to 5 times greater than their diameter, fixed on one end and provided with a stiffening ring (frame) at the free end, are discussed. Lines of influence, obtained experimentally with the use of celluloid models, are used to determine the normal and shearing forces, and bending moments acting on the frame. The method can be applied to stress analysis of any anisotropic shell, and to cases where the analytical solution is either impossible or involves considerable difficulties.

775. Kan, S. N. The stability and natural vibrations of cylindrical sandwich shells. PMe v. 8, no. 2 120-132

The dynamic behavior of a circular cylindrical sandwich shell under uniform radial pressure and axial pressure uniformly distributed along its circumference is discussed.

776. Petrov, V. V. (Saratov Polytechnical Institute). State-of-stress analysis of plates and shallow shells under finite deformations by the stepwise-loading method. PMe v. 8, no. 4 352-357

An approximate method of solving nonlinear

differential equations which describe the state of stress of plates and shells is proposed. The whole load acting on the structure is divided into parts which are applied stepwise until the structure is fully loaded. The steps are so selected that the deformations are small compared with the thickness of the structure, and a linear load-deflection relationship can be assumed.

777. Yershov, N. F. The equilibrium of flexible elastic-plastic shells and plates. PMe v. 8, no. 5 489-499

Expressions showing the effect of the local plastic deformations (buckling) of plates and shells under loading beyond their critical state are derived in terms of strain and stress functions. It is assumed that these bucklings (treated as initial imperfections) are small if compared with the thickness of the plate (shell). The post-buckling behavior of rigid plates (where Euler stresses are near the yield point of the material) is also indicated.

778. Tsurpal, I. A. Experimental determination of constants of the nonlinear elasticity theory. PMe v. 8, no. 5 555-563

The constants of H. Kauderer's law of non-linear elasticity — the bulk modulus, the shear modulus, and functions defining the physical nonlinearity of the material — were determined experimentally, plotted on stress-strain planes, and approximated by fitting polynomial curves. The procedure for determining the constants from diagrams is outlined.

779. Karpov, M. I. Strength problems of stiffened shells. PMe v. 8, no. 6 619-626

The strength of a circular cylindrical

shell stiffened by equally spaced stringers of identical geometric and elastic characteristics is discussed. The faces of the shell butt against diaphragms rigid in their planes but easily deformable in the transverse direction. The shell is under arbitrary external loading, and its strength is treated as a contact problem.

780. Ryzhov, O. S. The energy of sound waves. PMMe v. 26, no. 2 317-319

Analytical expressions for sound-wave energy are derived.

781. Ryzhov, O. S., and G. M. Shefter. Energy of sound waves propagating in moving media. PMMe v. 26, no. 5 854-866

An equation is derived describing sound-wave propagation in arbitrary nonuniform moving media, and an investigation is made under the assumption that the width of the perturbed gas is small as compared with the radius of shock-wave curvature and with the distance over which the initial parameters of the medium change substantially.

782. Nigul, U. K. Asymptotic theory of statics and dynamics of circular cylindrical shells. PMMe v. 26, no. 5 923-930

A linear theory of the statics and dynamics of elastic, circular cylindrical shells is developed on the basis of an asymptotic approximation of the three-dimensional elasticity theory. From this asymptotic theory it is possible to determine, with a small asymptotic error, the slowly changing state of stress in the shell.

783. Librescu, L. The dynamic problem of shallow viscoelastic thin shells. Rev MeAp v. 7, no. 4 781-795

The vibrational behavior of thin shallow shells of constant thickness made of viscoelastic, isotropic, homogeneous, physically linear material of the Maxwell type is discussed under the assumption that the Kirchhoff-Love hypothesis is valid.

784. Dol'berg, M. D., and V. I. Malykhin. A general design method for shells of revolution under symmetrical loading. RaProKon, Sb no. 8 M. 1962 47-68

An approximate method of structural mechanics for investigating the states of stress and strain of symmetrically loaded thin-walled shells of revolution with an arbitrarily shaped meridional section is proposed. The method is similar to Ritz's; however, it ensures the convergence of successive approximations to the exact solution, and thus facilitates determination of the value of the error.

785. Kan, S. N. The stability and static and dynamic strength of circular cylindrical sandwich shells. RaProKon, Sb no. 8 M. 1962 69-83

Problems in designing circular cylindrical sandwich shells -- for flexure, stability, and vibration -- are discussed under the assumption that there is a distortion in the cross-sectional contour of the shell. The conventional hypothesis of infinite rigidity of the core layer in the radial direction and zero rigidity in other directions is accepted. The flexure of a thin sandwich shell stiffened by circular frames rigid in their planes is investigated under arbitrary loading and support conditions. The stability and vibrational behavior of simply supported and clamped shells are examined.

786. Kan, S. N. The strength, stability, and load-carrying capacity of constructionally orthotropic cylindrical shells. — RaProK Sb no. 8 M. 1962 85-106

The problems of flexure, and elastic and plastic stability under radial pressure and uniform axial compression, and load-carrying capacity of constructionally orthotropic cylindrical shells are investigated. Cylindrical shells stiffened by stringers and circular frames and shells made from corrugated sheets are discussed, with the effect of the stiffening (or of corrugation) taken into account by introducing equivalent thicknesses and flexural rigidities in both axial and circumferential directions.

787. Moiseyev, N.N Variation problems in the theory of oscillation of liquid and liquid-filled bodies. — AN Vych Ts Monogr. Variats. Metody M. 1962 7-118

The use of variational methods in solving the problems of oscillation of bodies filled with liquid is discussed and substantiated. The stability of the body-liquid system is investigated. The convenience of the methods for use on electronic computers is emphasized.

788. Bublik, B. N., and V. I. Merkulov. Dynamic stability of liquid-filled rib-stiffened thin elastic shells. — AN Vych Ts Monogr. Variats. Metody M. 1962 119-178

The dynamic stability of thin, stiffened, elastic shells filled completely or partially with an ideal incompressible liquid is analyzed by using variational methods. The stiffeners are flexurally rigid in a plane normal to the middle surface and are rigid in tension (compression); their joint deformation with the shell is secured. The shell-liquid system described is acted on by arbitrary time-dependent loads applied to the shell surface.

789. Kuznetsov, A. P., and L. M. Kurshin. The stability of circular cylindrical shells under creep conditions. ZhPMeTF no. 3 66-72

The creep stability of hollow cylinders is investigated on the basis of analysis of accelerations of disturbed motions. In this respect, a shell is stable (unstable) when a disturbance in the form of an initial buckling causes a decrease (increase) in the rate of its development. It is assumed that stresses in the shell before buckling are distributed uniformly along its thickness and are not time dependent.

790. Kuzmak, G. Ye., V. K. Isayev, and B. Kh. Davidson. Optimal regimes for motion of a variable mass point in a homogeneous central field. 1963 ~~DAN~~ SSSR v. 149, no. 1 58-61

The optimal regimes for controlling the reactive thrust and its angle of inclination in a plane motion of a variable-mass point in a homogeneous central gravitational field are established by using Pontryagin's maximum principle.

791. Kil'chyns'ka, G. A. The thermoparametric resonance of a circular cylindrical shell in an unsteady temperature field. DopAN UkrSSR no. 1 40-44

The influence of a nonstationary, periodically changing temperature field on the stability of a simply supported circular cylindrical shell without external loading and initial stresses in the middle surface is analyzed under the assumptions that the temperature over the shell thickness and the dependence of the elasticity modulus and of the thermal expansion coefficient on the temperature are all linear.

792. B. M. Bublyk. Vibration and stability of a stiffened cylindrical shell in a compressible flow. DopAN UkrSSR no. 2 178-183

The vibrational and buckling behavior of a simply supported, closed, elastic, cylindrical shell with a discrete arrangement of stiffening frames is investigated. The shell is in a potential flow of inviscid fluid along its longitudinal axis.

793. Valilenko, M. V., and Yu. O. Klikh (Institute of Cermets and Special Alloys, Academy of Sciences UkrSSR). Mechanical vibration in a variable-temperature field. DopAN UkrSSR no. 5 592-595

The applicability of asymptotic methods, developed by Yu. N. Mitropol'skiy for investigation of transient processes with a small variation of parameters per cycle in nonlinear vibratory systems, is illustrated by a sample analysis of forced vibrations of a system with a single degree of freedom (a cantilever bar with a large mass at the free end) in a time-variable temperature field.

794. Goncharenko, V. M. (Kiev Polytechnical School). Determining the average time of snapping of a cylindrical panel under a random pressure. DopAN UkrSSR no. 6 736-7

The time-related buckling behavior of a shallow oblong cylindrical panel under uniform normal pressure combined with stationary random perturbances which speed up its buckling, is discussed. The load-carrying capacity of the panel can be estimated from the duration of the time interval up to buckling.

795. Manevych, A. I. Optimum design of a stiffened cylindrical shell under uniform external pressure. DopAN UkrSSR no. 7 875-878

A medium-length or a long cylindrical

shell of given wall thickness divided axially into sections by frames of different rigidity and subjected to uniform external pressure is discussed, assuming the same buckling stability in all sections. The rigidity parameters for shells with one, two, and three frames are determined. The attaining the equistability by changing either the spacing or the rigidity of frames is mentioned.

796. Karpov, N. I. (Institute of Mechanics, UkrSSR). On free vibration of a stiffened cylindrical shell. DopAN UkrSSR no. 8 1018-1021

A method of solving the almost unsolvable problem of free vibrations of a shell with a discrete spacing of stiffeners is presented. The method based on exact compliance with vibration equations of a stiffened shell yields an expression for frequencies in the form of a transcendental equation which is convenient for the qualitative investigation of the frequency spectrum and for numerical computations as well. The problem is treated as a contact problem in the theory of shells.

797. Antipov, O. O. (Nikolayev Shipbuilding Institute). Flexure of sandwich plates under nonuniform heating. DopAN UkrSSR no. 11 1441-1447

The flexure of asymmetrical sandwich plates with a rigid isotropic core and faces of different thickness made of different materials is analyzed. Flexure parameters of such a plate compressed in its plane under lateral loading combined with nonuniform heating (by a linear source) are determined.

798. Aleksandrov, G. V., and V. K. Svyatodukh. Controllable motions of winged aircraft in the plane of symmetry. InZh v. 3, no. 1 3-11

Controllable motions of aircraft of various

design configurations (conventional, canard, and pivoting wing) with respect to the relative position of the control force and the center of gravity are studied. An attempt is made to determine the specific nature of the aerodynamic characteristics inherent in the various layouts by taking the control force Y_δ into account.

799. Karnozhitskiy, V. P. Stability of a simply supported sandwich plate under pure flexure. — InZh v. 3, no. 1 183-186

The buckling behavior of simply supported symmetrical sandwich plates subjected to bending in two orthogonal directions is examined under the assumption that the hypothesis of straight normals is valid for the outer layers and that the core-layer material obeys the general relationships of the elasticity theory.

800. Livanov, K. K. (Institute of Mechanics, Academy of Sciences USSR). Axisymmetrical vibration of cylindrical shells in a supersonic gas flow. — InZh v. 3, no. 2 322-330

A method of investigating axially symmetrical vibrations of a cylindrical shell in a supersonic gas flow along its longitudinal axis is given. The method produces an exact solution when inertial forces due to all displacement components are taken into account. The vibrational behavidr of the shell in quiet gas (or in vacuum) is also discussed.

801. Kukudzhanov, V. N. (Moscow). Propagation of spherical waves in a viscoelastic medium. — InZh v. 3, no. 3 472-481

The propagation of spherical waves is investigated in an infinite linear viscoelastic solid having a spherical cavity on

whose boundary a time-dependent, uniform impulse pressure (or velocity) is applied.

802. Tryanin, I. I. (Gor'kiy). The effect of transverse loading on the stability and skin-participation factors of a continuous multipanel plate under compression. InZh v. 3, no. 3 504-512

The buckling stability of an infinite elastic plate with an orthogonal system of equidistant stiffeners simply supporting the skin is investigated. The plate is under uniform continuous transverse load and is compressed along the stiffeners in one direction, either tension or compression is applied to the plate along the stiffeners in the other direction.

803. Sokolovskiy, V. V. (Institute of Mechanics, Academy of Sciences USSR). Plastic flexure of a circular plate. InZh v. 3, no. 3 563-568

The flexure of a circular plate, simply supported on the edge, beyond the elastic range is discussed. The plastic-bending behavior of the plate under normal pressure is examined over the whole area of the plate and over the area of a smaller concentric circle.

804. Kozarov, M. (Sofia). The stability of orthotropic shells under temperature effects. InZh v. 3 no. 3 579-584

A system of differential equations for solving problems associated with the thermoelastic stability of orthotropic circular cylindrical shells is derived, starting with Love's basic equilibrium equations for isotropic shells and assuming a membrane-stress state of the shell prior to buckling. Thermal

buckling of a shell in a temperature field is investigated. This buckling is caused by a considerable difference in temperatures of the skin and of inner shell elements.

805. Darevskiy, V. M, (Moscow). Stability equations of cylindrical shells. InZh v. 3, no. 4 658-664

General differential equations describing the buckling behavior of medium-length cylindrical shells under torsion combined with axial compression are derived.

806. Kalinin, V. N. Equations of motion of an artificial earth satellite. IskSpZe no. 16 238-245

A complete system of exact differential equations is derived which describe the controlled motion of a satellite with a single constraint: that the gravitational field must be central. The equations derived will facilitate the study of such maneuvers as automatic approach on the orbit, or maneuvering in close vicinity of the orbit. A coordinate system moving along a central elliptic orbit and a fixed one (in the center of Earth) are used. Systems of approximate (linear) equations are also deduced.

807. Shamiyev, F. G. The design of minimum-weight shells. IzAN AzerSSR FMTN no. 5 37-41

The yield conditions for the maximum reduced stress is used to obtain the lower limit in the minimum-weight problem of a cylindrical shell under uniform internal pressure.

808. Bagdasaryan, Zh. Ye. On the stability of orthotropic shallow shells in supersonic gas flows. IzAN MeMa no. 1 92-98

The flutter behavior of a thin, orthotropic, rectangular, simply-supported, shallow, constant-thickness shells of constant double curvature is discussed in linear formulation. There is a supersonic gas flow on one side of the shell. The effect of transverse displacements on the flutter parameters is analyzed. A qualitative analysis in the case of a weak aerodynamic nonlinearity is given.

809. Kabanov, V. V. Stability of a circular cylindrical shell under nonuniform compression. IzAN MeMa no. 1 181-183

The linear problem of the local stability of a circular, closed, cylindrical shell under circumferential axial compression forces distributed along the face edges according to the cosine law is discussed. The shell is abutted on its faces against rigid diaphragms.

810. Grigolyuk, E. I., and D. D. Chulkov. Theory of sandwich shells with a rigid core. IzAN MeMa no. 2 75-80

The vibrations of an arbitrarily shaped sandwich shell with face layers and core of different constant thicknesses and ma of different orthotropic materials is discussed. The Kirchhoff-Love hypothesis is valid for the faces; the core is rigid; compressibility in transverse direction is approximated by linear functions.

811. Landa, P. S., and Yu. V. Ponomarev. A simulation method for boundary value problems. IzAN MeMa no. 2 75-80

A method is presented for the solution of

natural vibration problems in linear inhomogeneous systems with distributed parameters by using electronic models with d-c amplifiers. The method can be applied to the eigenvalue problems with boundary conditions of a general type and also to the solution of the problem of self-induced vibrations (for example, wing flutter problems).

812. Lamper, R. Ye., and L. G. Shandarov (Novosibirsk). Theoretical and experimental investigation of self-induced vibrations of cylindrical shells in a gas flow. — IzAN MeMa no. 3 58-64

The dynamic stability of finite-length cylindrical shells and curved panels in a supersonic gas flow parallel to their generatrices is discussed, taking into account the aerodynamic excess pressure generated by flow disturbances caused by the normal displacements of the shell surface. Special attention is paid to peculiarities in designing short cylindrical shells and panels.

813. Bolotin, V. V. (Moscow). On the theory of laminated plates. — IzAN MeMa no. 3 65-72

The equations of flexure, with boundary conditions, of elastic plates built up of n "rigid" and n-1 "soft" alternate laminas, both of constant thickness, are derived. The behavior of this "multilayer sandwich" under normal continuous load is discussed.

814. Pal'mov, V. A. (Leningrad). Dependence of stress concentration on the surface quality of machined parts. — IzAN MeMa no. 5 60-66

The stress distribution over the surface of machined parts is discussed and the stress-concentration factor is determined.

The surface roughness is regarded as a model of a stochastic field with certain statistical stress characteristics which are determined by the methods of the random-function theory. Asymptotic methods are used in cases of minute surface-roughness heights.

815. Aksel'rad, E. L. (Leningrad). Designing a corrugated diaphragm as a nonshallow shell. IzAN MeMa no. 5 67-76

Equations for large axisymmetrical displacements in elastic shells of revolution previously derived by the author are transformed to a form suitable for determining large deflections of rotationally symmetrical corrugated diaphragms of an arbitrary cross-section profile with various types of rim clamping. The effect of geometrical corrugation parameters (amplitude, wavelength, thickness, diameter of the flat central part) on the pressure-deflection characteristics is discussed.

816. Mushtari, Kh, M. The range of applicability of approximate theory of asymmetrical sandwich plates. IzAN MeMa no. 5 176-178

An approximate theory of asymmetrical sandwich plates based on the hypothesis that the transverse shear in the core layer is constant over its thickness is shown to be applicable to a large number of flexural problems concerning sandwich plates. The validity of the theory is demonstrated in the case of the cylindrical flexure of a simply supported plate under a lateral load acting on the upper face layer.

817. Darevskiy, V. M. (Moscow). Determining the critical pressure for a cylindrical shell stiffened by arbitrarily spaced rings of different rigidity. IzAN MeMa no. 3 73-82

The author's method for stability analysis of a cylindrical shell stiffened by equally-rigid equidistant rings and subjected to external normal pressure is generalized to the case of a cylindrical shell with simply supported faces and stiffened by arbitrarily spaced rings of different rigidities.

818. Pal'mov, V. A. (Leningrad). Stress concentration close to the rough surface of an elastic solid. — IzAN MeMa no. 3 104-108

The concentration of stresses caused by the surface roughness of machined parts is discussed. A sample expression for the stress-concentration factor is derived.

819. Kononenko, V. O. (Moscow). On oscillations of a body about its centroid. — IzAN MeMa no. 4 23-30

The oscillation of a body joined by elastic springs to a stationary frame and subjected to the action of external moments is investigated. The center of body's mass is immovable and the moments directly excite oscillations about only one coordinate axis. Cases of indirect excitation of oscillations about other coordinate axis are discussed in nonlinear formulation. Stability conditions of a disc, a sphere, and a cylinder are discussed and pertinent equations are derived.

820. Kan, S. N., and D. Ye. Lipovskiy. Combined compression and flexure of stiffened circular cylindrical shells. — IzVUZ, AvT no. 1 33-47

The states of stress and strain of circular cylindrical shells stiffened by stringers and rings are analyzed. The shells are subjected to transversal loading combined with axial compression uniformly distributed

along the faces. The effect of manufacturing imperfections of the shell's middle surface is taken into account. The problem is discussed in a linear formulation under conventional assumptions of the theory of elastic thin shells.

821. Malkina, R. I., and V. G. Godzevich. Free vibrations of zero-curvature shells. IzVUZ, AvT no. 1 48-57

Axially symmetrical free vibrations of arbitrary cylindrical and conical shells are discussed under the assumption of multiwave deformation. The differential equations of V. Z. Vlasov for arbitrary shallow shells with a large index of variation are simplified for the case of zero curvature and used to analyze the vibrational behavior of noncircular cylindrical and circular conical shells.

822. Rabinskiy, N. L. Designing cantilever plates by Vlasov's variational method. IzVUZ, AvT no. 1 58-65

An approximate method of designing cantilever plates of constant cylindrical rigidity is developed. Plates with planforms of the type used chiefly for airplane wings — rectangular, tapered, and triangular — are discussed.

823. Kurshin, L. M. On derivation of variational equations for a shallow cylindrical shell with thermal stresses taken into consideration. IzVUZ, AvT no. 1 151-156

The principle of virtual displacements with introduction of two potential functions (in forces and in displacements) is used in the derivation of variational stability equations for the force-deflection relationships (including thermal buckling) of a heated thin shallow cylindrical shell under final deflections. The fundamental relationships of

shallow shell theory are used as initial equations.

824. Kan, S. N., and D. Ye. Lipovskiy. Load carrying capacity of stiffened, thin, circular cylindrical shells under [axial] compression. IzVUZ, AvT no. 2 34-43

The article concludes the work of the authors which was published in IzVUZ, AT, no. 4, 1962 [79], and no. 1, 1963 [33], by presenting a simple method for predicting the load-carrying capacity of a thin compressed circular cylindrical shell stiffened by a system of frames and stringers and discussing the effect of various constructional parameters on the shell strength.

825. Kogan, B. I., and A. F. Khrustal'yev. The temperature field in an infinite shallow cylinder. IzVUZ M no. 2 60-62

The problem of determining the stationary temperature field in an infinite shallow cylinder is studied. The inner surface of the cylinder has a constant temperature; half the outer surface has a different constant temperature, while the other half radiates heat into the surrounding medium according to Newton's law.

826. Kan, S. N. Load carrying capacity of circular cylindrical shells under flexure. IzVUZ, AvT no. 4 63-69

The determination of the load carrying capacity of a circular cylindrical shell from the view point of the local strength of its material (not of buckling as a whole) is presented. Problems of a horizontal plain cylindrical shell subjected to pure flexure combined with uniform radial pressure are discussed.

827. **Kaplan, Yu. I. Analysis of axisymmetrical state of stress in cylindrical shells with discretely spaced elastic frames.** IzVUZ, AvT **no. 4** **70-78**

The effect of discretely spaced transverse frames on the strength stability, and free vibration of cylindrical shells is examined. It is assumed that the end frames are either rigid or elastic, and the intermediate ones are elastic in their plane and perfectly pliable out of it. The strength of shells under axisymmetrical loading and under flexure combined with compression, is investigated.

828. Ivanyuta, E. I., and R. M. Finkel'shteyn. Investigating the axisymmetrical vibration of cylindrical shells. LGU, MMe IslUpPro, Sb no. 2 90-104

The possibility of simplifying the initial equations for axisymmetrical vibrations of cylindrical shells is studied in order to obtain the engineering dynamical-shell-design formulas. A system of homogeneous algebraic equations is derived from which the whole frequency spectrum of torsional and combined longitudinal-flexural vibrations can be determined.

829. Chernykh, K. F., and V. A. Shamina (Shell Theory Laboratory, Institute of Mathematics, Leningrad State University). Designing toroidal shells. LGU, MMe IslUpPro, Sb no. 2 247-346

Work is being carried out to systematize and further develop design methods for toroidal shells. In this presentation of the first part of the planned work, the basic general methods for designing toroidal shells under conditions of symmetrical loading are discussed. A chronological critical review of Soviet and non-Soviet works in the field of toroidal-shell design showing the development of the art is presented, and a list of 46 Soviet and 36 non-Soviet references is given.

830. Karavanov, V. F. (Candidate of Technical Sciences). On large deflections of a clamped cylindrical light-core-sandwich panel under uniform normal pressure. MoAvI Vopr0sy pro. no. 1 97-109

Large deflections of a rectangular, cylindrical, shallow, symmetrical light-core-sandwich panel, built-in on all edges, are determined in the first approximation. The panel is under uniform normal pressure acting on its convex side; the materials of its faces and core are isotropic, homogeneous, and elastic.

831. Nasarov, M. O. (Leningrad Technological Institute). Free vibrations of circular cylindrical and shallow stiffened shells. PMe v. 9, no. 3 249-258

The vibrations of shells stiffened by stringers and transverse ribs or frames, the tangential rigidity and torsion of which are neglected, are investigated. The Ostrogradskiy-Hamilton variational principle is applied, and an equation for determining the natural frequency is derived.

832. Karnaukhov, V. G. Analytical solutions of free-vibration and stability problems of conical shells. PMe v. 9, no. 3 259-263

Simplified Mushtari-Donnell-Vlasov stress-strain equations are used to establish exact theoretical solutions in the analysis of free vibration and constructional stability of cylindrical conical shells under combined axial compression and external normal pressure.

833. Karpov, M. I. (Institute of Mechanics, UkrSSR). Stress and strain analysis of a shell with unequally spaced stringers. PMe v. 9, no. 3 270-274

The problem of the stress of a circular cylindrical shell stiffened by arbitrary spaced stringers having different geometric and elastic parameters is treated as a contact problem of the theories of shells and beams.

834. Kan, S. N. (Khar'kov Higher Aeronautical Engineering School). Load carrying capacity of stiffened and corrugated circular cylindrical shells under compression. PMe v. 9, no. 5 465-472

An attempt is made to develop a relatively simple method for determining the load carrying capacity of constructionally orthotropic (stiffened or corrugated) circular cylindrical thin-walled shells under axial compression. The L. C. C. is determined not from buckling conditions, but from crushing stresses of the material. Symmetrical and asymmetrical manufacturing irregularities are taken into account.

835. Komisarova, G. L. (Institute of Mechanics, Academy of Sciences UkrSSR). Longitudinally corrugated cylindrical shells of the optimum profile. PMe v. 9, no. 5 473-479

The problem of finding that form of corrugations which will ensure a maximum buckling load for a corrugation-cross-section cylindrical shell of a given weight is discussed.

836. Lur'ye, A. I. Free fall of a mass point in the cabin of a satellite. PMMe v. 27, no. 1 3-9

The path and velocity in a free fall of a mass point in the cabin of a satellite performing a free flight (in the presence of gravity only) and in a flight when nongravitational forces (such as those caused by aerodynamic drag of the satellite) are present, are discussed.

837. Tokarev, V. V. The effect of random deviations from the optimum-thrust program on the motion of a variable-mass body with a constant power expenditure moving in a gravitational field. PMMe v. 27, no. 1 27-32

The problem is reduced to determining the minimum averaged value of the increment of a characteristic acceleration (due to the thrust) functional. The random errors (stipulating this increment) incurred in realization of the optimum-thrust program which cause deviations from the calculated trajectory are discussed as well as the corrections of the thrust, their number, and distribution.

838. Chernyshov, G. N. Thin elastic shell of arbitrary shape subjected to concentrated forces and moments. PMMe v. 27, no. 1 126-134

The characteristic features in stress-strain relations are studied in the vicinity of points where concentrated forces or moments are applied. The results of previous investigations by other authors are generalized.

839. Suvorov, Yu. P. Spreading of thermal stresses in an elastoplastic bar. PMMe v. 27, no. 2 383-389

Propagation of stress waves in a semifinite elastoplastic bar caused by sudden heating of its free end was studied. Time-dependent thermal-stress distribution was assumed. A nonlinear heat-conductivity equation was used. Elastic and plastic regions in the bar were noted. The shock-wave action is described.

840. Gol'denveyzer, A. L. (Moscow). Development of an approximate shell theory by asymptotic integration of the elasticity-theory equations. PMMe v. 27, no. 4 593-608

An asymptotic method of integrating the differential equations of elasticity theory is proposed, by means of which an approximate theory of shells can be established with the desired degree of accuracy in a way analogous to that used for developing an approximate theory of flexure of plates in the author's article published in PMMa, v. 26, no. 4, 1962.

841. Karavanov, V. F. (Candidate of technical sciences). Stability and large deflections of oblong shallow cylindrical light-core-sandwich panels under uniform continuous transverse load. RaPro, Sb no. 9 280-301

An exact solution to the equilibrium problem of an oblong, shallow, cylindrical, sandwich panel under normal uniform pressure over its convex surface is presented, based on the theory of shallow sandwich shells with a light-weight core layer. The flexural rigidity of the face layers is not considered.

842. Vol'mir, A. S. Problems in elastic-system stability. UstoychivUpSis Monogr. 1-879

In his recent book, *Stability of Elastic Systems*, A. S. Vol'mir summarizes modern methods of investigating the elastic and plastic buckling of columns, plates, and shells (mainly thin-walled) and presents an extensive Soviet and non-Soviet bibliography (468 items). In the concluding article, "Some Problems for Further Investigations" (pp. 837-840), he enumerates the "urgent problems in the theory of stability of elastic systems."

843. Volkov, A. N. Conference on the theory of shells and plates. VeAN SSSR no. 1 123

The Fourth All-Union Conference on the

Theory of Shells and Plates, called by the Presidium of the Academy of Sciences, Armenian SSR, was held in Yerevan', 24 to 31 October 1962, and was attended by 437 representatives of academic, departmental, and industrial scientific research institutes, and planning and design bureaus. The work of the conference was carried out by five commissions devoted to the following topics: 1) general problems of the theory of shells and plates; 2) stability and nonlinear problems; 3) dynamics; 4) thermoelasticity, creep, and plasticity; and 5) structural mechanics. A total of 181 papers were presented in the sessions.

844. Ivanov, G. V. (Novosibirsk). On plastic stability of a cylindrical shell under axial compression. ZhPMeTF no. 3 111-116

The axisymmetrical buckling of a cylindrical shell subjected to axial compression is examined under the assumptions that the material of the shell is incompressible and the strain-hardening process is linear.

845. Chernous'ko, F. L. (Computing Center, Academy of Sciences, USSR). Motion of a solid with a cavity containing a perfect liquid and air bubble. 1964 ~~PMM~~ v. 28, no. 4 735-745

The motions of a solid, of a perfect incompressible liquid filling out a cavity in the solid, and of the center of a spherical, nondeformable, movable air bubble formed in the liquid are studied. The motion of the solid-liquid-bubble system is described by energy equations using its momentum and kinetic energy. Particular cases of translatory and rotary motions are analyzed as well as the effect of forces and moments suddenly applied to this system on its motion.

846. Rumyantsev, V. V. Motion stability of a solid filled with liquid possessing surface tension. PMMe v. 28, no. 746-753

The motion of a solid having a cavity filled with two non-mixing perfect incompressible liquids possessing surface tension is investigated. Given potential forces are acting on the solid, and mass forces on the liquids. The Hamilton-Ostrogradskiy principle of least action is used in deriving the equations of the motion of the system with the boundary conditions. The application of the results obtained to the viscous liquids filling the cavity is indicated.

847. Petrov, A. A. (Computing Center, Academy of Sciences, USSR). Variational formulation of the motion of liquid in a finite-dimension vessel. PMMe v. 28, no. 754-758

The nonlinear problem of oscillation of an ideal incompressible liquid in a vessel of finite dimensions is discussed in variational formulation. The liquid partially fills the vessel; the rest is filled with gas. The kinetic and potential energies of the system are considered in determining the Lagrange function and the Hamilton action integral from which the solution of the problem is obtained.

GROUP E MISCELLANEOUS

Acoustic and Sonic Boom
Auxiliary Devices

848. Rybakov, A. I. The rotational motion of a celestial body around its center of mass. — 1959 MGU, GAI, Soob no. 112 33-41

Results are given of the numerical integration of differential equations of the rotational motion of a homogenous mass segment when the length of the segment is sufficiently small.

849. Novozhilov, V. V. (Leningrad). Displacement of a perfectly rigid body under action of an acoustic pressure wave. — PMM v. 23, no. 4 794-796

A pressure wave propagated in an infinite fluid strikes a body at rest (immersed in the fluid) with a finite impulse, and causes its finite displacement. The body is perfectly rigid and its density can be higher, equal, or lower than that of the fluid (displacements due to the buoyancy are neglected). The body has two orthogonal planes of symmetry (as related to its shape and mass distribution) which are perpendicular to the wave front. The possibility of solving this problem for a body of arbitrary shape is briefly discussed.

850. Fayzullov, F. S. (Physics Institute, Academy of Sciences USSR), N. N. Sobolev, Ye. M. Kudryavtsev. A spectroscopic investigation of the state of gas behind a shock wave. III. — OpSpe v. 8, no. 6 761-768

The results of an investigation using the generalized spectrum-line reversal method to measure the temperature of nitrogen and air behind a shock wave in the range of shock-wave velocities from 1.9 to 4.3 km/sec, and for gas pressures in the plug from 0.1 to 4 atm are presented. The distribution of temperatures along the plug is studied for various shock wave velocities.

851. Stanyukovich, K. P. A phenomenon in meteor aerodynamics. — 1960, [illegible], no. 5, 3-6

Equations are given which define phenomena of the motion of meteors at a speed of 18 to 20 km/sec and an altitude of 100 km.

852. Sayasov, Yu. S. The kinetics of ionization behind a normal shock wave in air. — 1962, DAN SSSR, v. 146, no. 2, 409-412

A theoretical study is made of the kinetics of electron processes taking place behind a shock wave propagating in air.

853. Kuznetsov, N. M. (Institute of Chemical Physics, Academy of Sciences USSR, Moscow). Kinetics of chemical reactions during air expansion. — InFZh, v. 5, no. 6, 97-101

The kinetics of chemical reactions occurring in expanding air (with subsequent adiabatic cooling) in the wake of hypersonic blunted bodies is discussed.

854. Vinogradov, R. I. Similitude and the oscillations of bodies in liquid flows. — IzVUZ, AvT, no. 4, 3-11

Complete similitude in the development of self-induced oscillations in an elastic body in an incompressible liquid is obtained.

855. Dronov, A. P., A. G. Sviridov, and N. N. Sobolev. Continuous emission spectra of krypton and xenon behind a shock wave. — OpSpe, v. 12, no. 6, 677-690

The brightness and energy distribution of the continuous spectra of krypton and xenon behind a shock wave were studied at Mach numbers from 11.5 to 15.

856. Krivtsova, N. V., and Yu. P. Lun'kin (Leningrad Physico-technical Institute). The excitation of molecule rotations behind a shock wave. ZhTF v. 33, no. 1 67-75

The effects of variations in gas flow parameters on the excitation of rotational degrees of freedom of the molecules beyond a shock wave are analysed. It is shown that the width of the relaxation region is sharply reduced with increasing Mach numbers of the incident flow. A monatomic impurity has only a slight effect on the width of the relaxation region.

857. Malkes, L. A., and N. V. Kirsanov. Release system for a deceleration parachute. 1963 BIzobr no. 17 100

A patent was issued for a mechanism for releasing a braking parachute with forced opening of the container compartment door in case of an emergency (accumulation of dirt or freezing) by using air cylinders connected with the compressed-air circuit of the aircraft.

858. Popov, Ye. I. (Institute of Physics of the Earth, Academy of Sciences USSR). Results of experimental airborne determinations of gravity acceleration. IzAN, IFZe no. 5

The purpose of the experiment was to determine the difference between the gravity acceleration on the ground and that in the air. In 1960 measurements were taken from an Il-14 aircraft equipped with three highly-damped GAL gravimeters suspended in gimbals, a gyrostabilized aerial camera with a 70-mm focal-length lens, two statoscopes, a radio altimeter, and two ranging devices (flight line indicators).

859. Grigolyuk, E. I. (Novosibirsk), and V. L. Prisekin (Novosibirsk). Dynamic interaction between an orthotropic cylindrical shell and an acoustic shock wave. Iz AN MeMa no. 6 25-35

Displacements in an infinite, constructionally orthotropic, thin, elastic, cylindrical shell due to interaction with a plane acoustic shock wave are discussed. The shell consists of a homogeneous isotropic elastic skin stiffened by an orthogonal system of identical, equidistant, elastic rings and stringers. The front of the incident acoustic shock wave is parallel to the generatrices of the shell.

860. Ivanov, Yu. N. (Moscow). Motion of a variable mass body with limited power and given active time. PMM v. 27, no. 5 854-863

Several authors have studied optimal working conditions for motion of a variable mass body with limited power of the reactive jet to find the optimal running time of the engines. The author generalizes these results by proposing a general method for solving the variational problem with given active time which is less than optimal. He formulates the variational problem for the case cited in the title and illustrates the general results by analyzing optimal motion in a plane-parallel gravitational field. He investigates two limiting cases for regulating a propulsion system: an ideally regulatable system (variable optimal thrust) and a nonregulatable system (constant thrust).

861. Krasovskiy, Yu. P.; M. A. Lavrent'yev; N. N. Moiseyev; A. M. Ter-Krikorov; A. B. Shabat (Novosibirsk, Moscow). Mathematical problems of the hydrodynamics of a liquid with free boundaries. ZhPMTF no. 4 3-16

The article reviews Soviet publications of the last four years dealing with investigations in the theory of motion of a liquid with free boundaries. Data available from the authors' survey reports presented at the IV Vsesoyuznyy matematicheskiy s"yezd (Fourth All-Union Mathematical Congress) in Moscow in 1958 are used in this paper.

Abbreviations of Sources Used in This Report

1.	AkZh	Akusticheskiy Zhurnal (Journal of Acoustics)
2.	AN GruzSSR, Soob Sb	Soobshcheniya, Sbornik, Voprosy dinamiki i prochnosti (Academy of Sciences Georgian SSR. Communications. Collected Articles. Problems of Dynamics and Strength of Materials)
3.	AN LatSSR, Sb IAvtMe, OFTN	Sbornik, Voprosy dinamiki i prochnosti (Academy of Sciences of Latvian SSR, Institute of Automation and Mechanics. Collected Articles. Problems of Dynamics and Strength of Materials)
4.	AN UkrSSR IMe	Academy of Sciences Ukranian SSR Institute of Mechanics
5.	AN Vych Ts	AN SSSR. Vychislitel'nyy Tsentr, Raschet osesymmetrichykh tel (Academy of Sciences USSR. Computing Center. Calculation of Axisymmetric Bodies)
6.	ApM	Aplicace Matematiky (Applied Mathematics, Polish)
7.	Arch BMa	Archiwum budowy maszyn (Records of Machine Building)
8.	Arch Me Sto	Archiwum Mechaniki Stosowanej (Records of Applied Mechanics, Polish)
9.	ASA SSSR I Str Kn, Tr	Academiya Stroitel'stva i Arkhitektury SSSR, Institut Stroitel'nykh Konstruktsiy, Trudy. (Academy of Construction and Architecture SSSR. Institute of Constructions, Proceedings)
10.	As Zh	Astronomicheskiy Zhurnal (Astronomical Journal)
11.	AvKos	Aviatsiya i Kosmonautika (Aviation and Astronautics)
12.	Avt Te	Avtomatika i Telemekhanika (Automation and Remote Control)
13.	AW	Akademie der Wissenschaften, Monatberichte, Berlin (Academy of Sciences, Monthly Report, Berlin. German)

14.	BIzobr	Byulleten' izobreteniy (Bulletin of Inventions)
15.	DAN SSSR	Doklady Akademii Nauk SSSR (Transactions of the Academy of Sciences USSR)
16.	DopAN, UkrSSR	Dopovidi Akademii Nauk (Transactions of the Academy of Sciences, Ukranian SSR)
17.	EnI, ANSSSR,	Energetichesk'y Institut. Academiya Nauk SSSR. Fizicheskaya Gazodinamika: Teploobmen (Power Engineering Institute, Academy of Sciences of USSR. Physical Gasdynamics and Heat Exchange)
18.	G Ast I	Gosudarstvennyy Astronomicheskiy Institut, Soobshcheniya (State Astronomical Institute, Moscow State University, Communications)
19.	IPMMe, ANSSSR Sib. O. Sb.	Institut Prikladnoy Matematiki i Mekhaniki Sbornik (Institute of Applied Mathematics and Mechanics, USSR Academy of Sciences, Sibirian Branch, Collected Articles)
20.	IKhM. Mn	Institut Khimicheskogo Mashinostroyeniya (Institute of Chemical Machine Building)
21.	InFI	Inzhenerno-fizicheskiy institut. (Engineering Physics Institute)
22.	InFZh	Inzhenerno-fizicheskiy Zhurnal (Engineering Physics Journal)
23.	In Zh	Inzhenernyy Zhurnal (Engineering Journal)
24.	In Sb	Inzhenernyy Sbornik (Engineering Review)
25.	IslTp	Issledovaniye teploobmena
26.	ISZ	Iskusstvennyye Sputniki Zemli (Earth Artificial Satellites)
27.	IzAN ArmSSR	Izvestiya Akademii Nauk Armyanskoy SSR (News, Academy of Sciences Armenian SSR)
28.	IzAN ArmSSR FMN	Izvestiya Akademii Nauk Armyanskoy SSR, Seriya Fiziko-Matematicheskikh Nauk (News, Academy of Sciences Armenian SSR, Physics and Mathematics Series)

29.	IzAN AzerSSR FMN	Izvestiya Akademii Nauk, Azerbaydzhanskoy SSR. Seriya Fiziko-Matematematicheskikh Nauk (News, Academy of Sciences Azerbaijain SSR, Physics and Mathematics Series)
30.	IzAN EnAvt	Izvestiya Akademii Nauk, Energetika i Avtomatika (News, Academy of Sciences USSR, Power Engineering and Automation)
31.	IzAN Me	Izvestiya Akademii Nauk, Mekhanika (News, Academy of Sciences USSR, Mechanics)
32.	IzAN MeMa	Izvestiya Akademii Nauk, Mekhanika i Mashinostroyeniye (News, Academy of Sciences USSR, Mechanics and Machine Building)
33.	IzAN OTN	Izvestiya Akademii Nauk, Otdeleniye Tekhnicheskikh Nauk (News, Academy of Sciences USSR, Department of Technical Sciences)
34.	IzAN SibO	Izvestiya Akademii Nauk, Sibirskoye Otdeleniye (News, Academy of Sciences USSR, Sibirian Branch)
35.	IzVUZ AvT	Izvestiya Vysshikh Uchebnykh Zavedeniy, Aviatsionnaya Tekhnika (News of the Higher Learning Schools, Aeronautical Engineering)
36.	IzVUZ M	Izvestiya Vysshikh Uchebnykh Zavedeniy. Matematika (News of the Higher Learning, Mathematics)
37.	IzVUZ Ma	Izvestiya Vysshikh Uchebnykh Zavedeniy, Mashinostroyeniye (News of the Higher Learning Schools. Machine Building)
38.	IzVUZ Pb	Izvestiya Vysshikh Uchebnykh Zavedeniy. Priborostroyeniye (News of Higher Learning Schools. Instrument Building)
39.	KAvI, Tr	Kazanskiy Aviatsionnyy Institut. Trudy (Kazan' Aviation Institute. Proceedings)
40.	KosIsl	Kosmicheskiye Issledovaniya (Space Research)

41.	Konf. TpMas	Konferentsiya po teploobmeny i massoobmenu (Conference on Heat and Mass Transfer)
42.	KPoI	Kievskiy Politekhnicheskiy Institut (Kiev Polytechnic Institute)
43.	LPoI TGi Tr	Leningradskiy Politekhnicheskiy Institut. Tekhnicheskaya Gidrodinamika Trudy (Leningrad Polytechnic Institute. Technical Hydro-dynamics, Proceedings)
44.	LU MMeFa Sb.	Leningradskiy Universitet Matematichesko-Mekhanicheskiy Fakul'tet (Leningrad University Department of Mathematics and Mechanics. Collected Articles)
45.	LU NIslIMMe	Leningradskiy Universitet Nauchno-Issledovatel'skiy Institut Matematiki i Mekhaniki (Leningrad University. Scientific Research Institute of Mathematics and Mechanics)
46.	Mo Av I, Tr	Moskovskiy Aviatsionnyy Institut, Trudy (Moscow Aviation Institute, Proceedings)
47.	MoFTI, Tr	Moscovskiy Fiziko-Tekhnicheskiy Institut, Trudy (Moscow Institute of Physics and Technology, Proceedings)
48.	MoU, Vych Ts Sb.	Moskovskiy Universitet, Vychislitel'nyy Tsentr, Sbornik (Moscow University, Computing Center, Collected Articles)
49.	MoVTU, Tr.	Moskovskoye Vysshe-Tekhnicheskoye Uchilishche, Trudy (Moscow Higher Technical Technical School, Proceedings)
50.	OpSpe	Optika i Spektroskopiya (Optics and Spectroscopy)
51.	PMe	Prikladna Mekhanika (Applied Mechanics)
52.	PMMe	Prikladnaya Matematika i Mekhanika (Applied Mathematics and Mechanics)
53.	Rev Me Ap	Revue de Mecanique Appliquee (Revue of Applied Mechanics, Ruman)
54.	RaPrKon Sb.	Raschety na Prochnost' Konstructsiy Teoreticheskiye i Eksperimental'nyye issledovaniya Prochnosti. Sbornik (Design for Strength, Theoretical and Experimental Investigations, Collected Articles)

55.	RZhM	Referationyy Zhurnal, Matematika (Journal of Abstracts, Mathematics)
56.	RZhMe	Referativnyy Zhurnal, Mekhanika (Journal of Abstracts, Mechanics)
57.	SibOAN MMe	Sibirskoye Otdeleniye Academii Nauk, Matematika i Mekhanika (Sibirian Branch of the USSR Academy of Sciences, Mathematics and Mechanics)
58.	S Phys (JETP)	Soviet Physics (English translation of Zhurnal Eksperimental'noy i Teoreticheskoy Fiziki see No. 75)
59.	StuCeMeAp	Studii si Cercetari de Mecanica Aplicata (Study and Research in Applied Mathematics, in Rumanian)
60.	Tp	Teploperidacha (Heat Transfer)
61.	Tpe	Teploenergetika (Heat Power Engineering)
62.	Tpf	Teplofizika (Thermophysics)
63.	TGi, Tr	Tekhnicheskaya Gidrodinamika, Trudy (Engineering Hydromechanics, Proceedings)
64.	TsAeGiI (TsAGI) Sb.	Tsentral'nyy Aerogidrodinamicheskiy Institut, Sbornik (Central Aero and Hydrodynamics Institute, Collected Articles)
65.	UsFN	Uspekhi Fizicheskikh Nauk (Progress in the Physical Sciences)
66.	UsMN	Uspekhi Matematicheskikh Nauk (Progress in Mathematical Sciences)
67.	UstUprSis	Ustoychivost' Uprugikh Sistem (Stability of Elastic Systems) (Monograph)
68.	VeAN	Vestnik Akademii Nauk (Herald of the USSR Academy of Sciences)
69.	VeLUMMeAst	Vestnik Leningradskogo Universiteta Seriya Matematiki, Mekhaniki i Astronomii (Herald of Leningrad University, Mathematics, Mechanics, and Astronomy)
70.	VeMoUMMe	Vestnik Moskovskogo Universiteta Seriya Matematiki i Mekhaniki (Moscow University, Mathematics and Mechanics)

71.	VpMe, Sb.	Voprosy Mekhaniki, Sbornik (Problems of Mechanics, Collected Articles)
72.	Vych M.	Vychislitel'naya Matematika (Computing Mathematics)
73.	WjPrzT	Wojskowy Przeglad Techniczny (Polish) (Air Force Review)
74.	ZhETeF	Zhurnal Eksperimental'noy i Teoreticheskoy Fizika (Journal of Experimental and Theoretical Physics)
75.	ZhPMeTF	Zhurnal Prikladnoy Mekhaniki i Tekhnicheskoy Fiziki (Journal of Applied Mechanics and Technical Physics)
76.	ZhTF	Zhurnal Tekhnicheskoy Fiziki (Journal of Technical Physics)
77.	ZVychMMF	Zhurnal Vychislitel'noy Matematiki i Matematicheskoy Fiziki (Journal of Computer Mathematics and Mathematical Physics)

Glossary of Abbreviations Used in This Report

Abbreviation	Russian, Czekh, German, Polish, Rumanian (transliterated)	English (translated)
A	Akademiya, Akademicheskiy	Academy, Academic
Ae	Aerodinamika, Aerodimicheskiy	Aerodynamics, Aerodynamic
Ak	Akustika, Akusticheskiy	Acoustics, Acoustic
Ap	Appliquee (Fr.), Aplicata (Rum.), Aplikace (Polish)	Applied
Ar	Arkhitektura	Architecture
Arch	Archiwum (Polish)	Archives
Arm	Armeniye (SSR), Armyanskiy (aya)	Armenia, Armenian
As	Astronomiya, Astronomicheskiy, Astronautika	Astronomy, Astronautics
Av	Aviatsiya, Aviatsionnyy	Aviation
Avt	Avtomatika, Avtomaticheskiy	Automation
Azer	Azerbayazhan (SSR), Azerbaydzhanskiy	Azerbaijan
B	Byulleten'	Bulletin
Bd	Budowy	Building, design (Polish)
Ce	Cercetari (Rumanian)	Research
D	Doklady	Reports, Proceedings
Dn	Dinamika	Dynamics
Dop	Dopovidi (Ukranian)	Transaction
E	Eksperiment, Eksperimental'nyy (aya)	Experiment, Experimental
En	Energetica, Energeticheskiy	Energetics, Power Engineering, Energy Producing
Est	Estoniya, Estonskiy	Estonia (SSR), Estonian
F	Fizika, Fizicheskiy	Physics, Physical
Fa	Fakul'tet	Department (in University, especially physics & mathematics)
G	Gosudarstvo, Gosudarstvennyy	State
Ga	Gaz, Gazodinamika	Gas, Gasdynamics
Gi	Gidravlika, Gidrodinamika, Gidrodinamicheskiy	Hydraulics, Hydrodynamics
Gruz	Gruziya, Gruzinskiy	Georgia (SSR), Georgian
I	Institut	Institute
In	Inzhener, Inzhenernyiy	Engineer, Engineering

Isk	Iskusstvennyy	Artificial
Isl	Issledovaniya, Issledovatel'skiy	Research
Iz	Izvestiya	Bulletin, News
Izd	Izdatel'stvo	Publishing House
Izobr	Izobreteniye	Invention
K	Kiev, Kievskiy	Kiev (city)
Kaz	Kazan', Kazanskiy	Kazan (city)
Khm	Khimiya, Khimicheskiy	Chemistry, Chemical
Kn	Konstructsiya	Construction, Design
Konf	Konferentsiya	Conference
Kos	Kosmos, Kosmicheskiy	Space
L	Leningrad, Leningradskiy	Leningrad
Lat	Latviya, Latviyskiy	Latvia (SSR), Latvian
Lit	Literatura	Literature
Lot	Lotniczy (Polish)	Flight
M	Matematika, Matematicheskiy	Mathematics, Mathematical
Ma	Mashinostroyeniye	Machine building
Mas	Massobmen	Mass transfer, Mass flow rate
Me	Mekhanika	Mechanics
Mo	Moskva, Moskovskiy	Moscow
Mokolas	Mokolas ir Technike (Hungarian)	Science and Technology
Monogr.		Monograph
N	Nauka, Nauchnyy	Science, Scientific
O	Otdeleniye	Department, Branch, Section
Op	Optika, Opticheskiy	Optics, optical
P	Prikladnaya, Prikladnoy	Applied
Pb	Priborostroyeniye	Instrument building
Po	Politekhnika, Politekhnicheskiy	Politechnic
Pro	Prochnost'	Strength
Prz	Przeglad (Polish)	Review
R	Referativnyiy	Reference
Ra	Raschet	Calculation, Design
Rev	Revue	Review
S	Soyuz, Sovet, Sovetskiy	Union, Soviet
Scientia Sinica		Chinese Science
Sb	Sbornik	Collection, Collected Articles
Sib	Sibir', Sibirskiy, Sibirskoye	Siberia, Siberian
Sis	Sistema	System
Soob	Soobshcheniye	Communication, Message Report

Sp	Sputnik	Satellite
Spe	Spectroskopiya	Spectroscopy
Sto	Stosowanej (Polish)	
Stu	Studium (Polish, Studii (Rumanian)	Studies
Str	Stroitel'stvo	Building, Construction
T	Tekhnika, Tekhnicheskiy	Technology, Engineering, Technical
Te	Teoriya	Theory
Tl	Telemekhanika	Telemechanics, Remote Congrol
Tm	Temperatura, Termicheskiy	Temperature, Thermal
Tp	Teplo, Teploenergetika, Teploobmen	Heat, Heat Power Engineering, Heat transfer
Tpr	Teplofizika	Heat physics
Tr	Trudy	Transactions, Proceedings
Ts	Tsentr, Tsentral'nyiy	Center, Central
U	Universitet, Uchilishche, Uchebnoye	University, School, Learning
Ukr	Ukraina, Ukrainskiy	Ukraine (SSR), Ukranian
Upr	Uprugost'	Elasticity
Us	Uspekhi	Progress
Ust	Ustoychinost'	Stability
V	Vysshiy, Vysshiye	High, Higher
Ve	Vestnik	Herald
Voe	Voyennyy, Voyennoye	Military
Vp	Voprosy	Problems
Voz	Vozdukh, Vozdushnyy (aya)	Air
Vych	Vychisleniye, Vychislitel'nyy	Computation, Computing
W	Wissenshaften (German)	Science, Scientific
Wj	Wojskowy przeglad Techniczny	(Air Force Review, Polish)
Z	Zavedeniye	Establishment, Institution, School
Ze	Zemlya	Earth
Zh	Zhurnal	Journal

APPENDIX C
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